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Research Natural Areas: Baseline Monitoring and Management

Proceedings of a Symposium in Missoula, Montana, March 21, 1984

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U.S. DEPARTMENT OF AGRICULTURE

Research Natural Areas: Baseline Monitoring and Management

Proceedings of a Symposium in Missoula, Montana, March 21, 1984

Coordinators:

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Sponsored by the U.S. Department of Agriculture, Forest Service, Northern Region and Intermountain Forest and Range Experiment Station; the University of Montana; Northwest Scientific Association; and Montana Academy of Sciences.

ACKNOWLEDGMENTS

The coordinators express appreciation to our sponsors for their support, to the Northern Region Research Natural Area Committee and The Nature Conservancy for their encouragement, to Dorothy Dryden for assuring completion of every task we undertook, to Louise Kingsbury for leading production of these proceedings, and especially to Steve Arno and Chuck Wellner who were catalysts to the idea and organization of the symposium.

We also express our special thanks to all our excellent speakers, to Jim Habeck, who helped as moderator, to the many displayers of top-notch posters, and to the 60 to 80 participants who joined with us throughout the symposium and shared their thoughts on how to improve the usefulness of research natural areas.

DEDICATION

Dedicated to Charles A. Wellner, recipient of The Nature Conservancy's coveted "Oak Leaf Award."

This award was presented by Dr. Steven C. Buttrick at this symposium to Chuck for his especially dedicated service to natural area ideals. Throughout his Forest Service career, Chuck was a major proponent for the establishment and scientific use of research natural areas. In 1974, after retirement, Chuck helped organize the Idaho Natural Areas Coordinating Committee, a select group committed to the preservation of undisturbed tracts of land and water for research and education. Chuck has been remarkably successful in proposing and helping to establish research natural areas in lands of the National Forest System, the State of Idaho, and the Bureau of Land Management. Chuck's interest spans the range of biological and physiogeographical attributes. His enthusiasm has been an inspiration to us all and has done much to foster the preservation of both representative and unique natural area sites.

CONTENTS

KEYNOTE COMMENTS: PROPHYLAXES FOR OUR RESEARCH NATURAL AREA SYSTEM

Jerry F. Franklin, presented by Robert D. Pfister

ABSTRACT: Three problem areas that could threaten the integrity of the research natural area system are discussed: (1) lack of scientific use; (2) inadequate documentation of the research methods and marking of installations in the field; and (3) inadequate management (stewardship) programs. Suggestions are made to remedy these conditions.

INTRODUCTION

Things are going well in our natural area programs. In most States, we either have or are developing comprehensive plans for natural area systems--plans that coordinate activities of many agencies and organizations. The Nature Conservancy's heritage programs are abetting the work with identification of elements or cells of interest and their locations. Natural areas are being incorporated into Forest Service land-use planning; many new research natural areas will presumably emerge. The Bureau of Land Management has greatly simplified its establishment procedures, releasing a tide of new research natural areas. States and The Nature Conservancy are identifying and protecting endangered habitats as a part of critical-area programs, one of which has just been successfully completed in California.

Some of the problems are obvious. When the National Forest plans are finalized, will all of the identified areas actually get established? Dollars are short for research and monitoring. In some States, including Oregon, State programs are high-centered, unable to get sufficient funds or agency support for establishment of natural areas.

Nonetheless, we could congratulate ourselves on our advances. Progress has been made in identification and establishment of areas, in general recognition of the value of research natural areas, and in acceptance of these programs by managers.

A keynoter--even in absentia--might be expected to deliver a positive statement. I choose not to make such a statement, however, for the dark clouds ahead could create major problems for our research natural area system unless appropriate measures are taken.

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Some potential dangers to our research natural area system are: (1) the minimal use by scientists of the existing research natural areas; (2) inadequate documentation of what has been done, including work intended to provide a long-term data base; and (3) insufficient attention to stewardship of reserves. My intention is to characterize these dangers and to propose some remedial actions. Without such prophylactic measures, I question whether our natural area system will persist.

USE IT OR LOSE IT

Establishing a research natural area or reserve does not insure its existence in perpetuity--regulation, law, or ownership, notwithstanding. Federal research natural areas are going to be reviewed periodically by the responsible agency. Land-use planning on the National Forests may mean, for example, a major round of establishing research natural areas after plans are adapted. But it also insures that this designation is going to be reviewed at 10-year intervals--at each planning cycle.

Many questions will be posed at each review. The most critical question may be, "Has anybody used this natural area?" However much we may argue (and believe) that reserves have value even without any use, managers and the public are going to find such arguments unconvincing. Managers already complain constantly of the real or imagined lack of scientific use of existing research natural areas. Each cycle of land-use planning--of reassessment--will be a moment of truth in which concrete evidence of use by the scientific community will be essential. Have we put our energies and our dollars where our mouths are?

The importance of using natural areas is not confined to Forest Service or Bureau of Land Management research natural areas. It will almost certainly come to apply to all lands exempted from normal social uses for scientific purposes. The Nature Conservancy and other private reserves are commonly granted tax exemptions based on scientific and other benefits to the public. We can be sure that this contribution will be periodically examined. Even areas designated as Wilderness or as National Parks are going to be periodically reassessed. Wilderness, in particular, has been justified partially on scientific grounds, but agency attitudes and regulations have relegated research to a minor activity; I expect to see an accounting for the paucity of research in Wilderness locations in the future.

Many factors contribute to low scientific use of existing research natural areas. Scientists often do not know of the existence and variety of ecosystems found in natural areas. Funds and time are short, discouraging use of a more remote site even though it is protected. I have heard scientists offer various rationales as to why they could not use an established research natural area or experimental forest; some of these scientists have been very vocal in insisting agencies establish them.

Natural scientists are responsible for seeing that appropriate use is made of natural areas in their own studies and those of others. We need to begin pointing out natural areas to fellow scientists, making the extra commitments of dollars or time necessary to use natural areas in our own work, and criticizing colleagues who fail to use appropriate areas for their research. Managing agencies, as well as the scientific community, must be kept informed of studies.

Funding agencies bear a special responsibility to see that scientists use appropriate research natural areas and other scientific reserves. This burden lies with the panels that provide peer reviews and recommendations, as well as program managers in organizations such as the National Science Foundation. Strong encouragement--even coercion of reluctant peers--may be justified.

The scientific community must begin to put up or shut up; if we do not use our scientific reserves we will almost certainly lose them. We need to take this responsibility seriously.

LEAVING TRACKS

Documentation is the key to any research or monitoring program that purports to be of long-term value. What were the objectives of the research? Where was the sampling conducted--the geographic location within the research natural area? Can the plots be relocated? What methods, instruments, were used? Where are the original data? Have they been duplicated and archived in a safe place? Have the data been entered in electronic form and subsequently verified?

I contend that--with a few notable exceptions--the scientific community has done an abominable job of plot monumenting and field marking, study documentation, and data archiving. How many times have we attempted to revisit old plots, use old data sets, repeat measurements, and so on--and been totally frustrated because we could not tell what had actually been done? Part of this is a consequence of an unwarranted belief in our individual abilities to recall critical information at some far-off date. Some of our failure is a consequence of laziness. Agencies contribute to documentation failures by regulations that unnecessarily limit field marking. Institutions discourage (directly or through their reward structures) long-term research perspectives. Many circumstances cause failures and few nurture documentation efforts.

We simply must get this area of field marking and documentation under control or little long-term research and monitoring will be worthy of the name--or the dollars invested in it.

Field marking is where the documentation job starts (not counting the initial study plan). Future scientists have to be able to relocate plots, which requires detailed maps or carefully marked aerial photographs, detailed instructions, and, often, route markings on the ground. In the rugged topography and dense vegetation of many forested mountain regions, relocating a plot can be difficult and time consuming. Plot markings themselves need to be permanent and often as conspicuous as possible. When it comes to marking plots, metal or plastic stakes are better than wooden, taller stakes typically better than shorter, and more stakes better than fewer. Yellow metal signs, 5 by 8 inches, tacked on trees and facing outward from plot edges have been very helpful in guiding researchers back to plots in the shrub- and tree-infested Neskowin Crest Research Natural Area on the Oregon coast. Metal tree tags are usually the fastest and surest way of identifying individual trees for remeasurement; simply tallying trees on a plot provides information of much more limited value and none on the behavior of individual specimens. And so forth.

I am sure that some of you take exception to some or all of these suggestions. I do not propose scientific license in the use of reserves, however, or use of conspicuous markings in recreationally sensitive areas. I do argue that we should use techniques that will provide for reliable and efficient remeasurement programs consistent with maintenance of natural processes. None of the field markings proposed above are likely to have a significant effect on natural processes, but objections to them are sometimes voiced, based primarily on esthetic considerations and not on concern for altered ecological processes. I think that such concerns are grossly misplaced, especially when activities that significantly alter natural processes--such as trapping, hunting, or grazing by domestic livestock--are allowed to continue in and around our research natural areas.

Data documentation and archiving are the other critical areas. During the first several decades of Forest Service research, establishing long-term plots was emphasized; excellent records were laboriously duplicated and maintained, methodologies were standarized or described in detail, and so on. Few modern researchers appear to take the time to protect and document their data sets adequately for the long term. They know what they did--so they often waste no time describing methods, variables, and so on.

Forest Service and university researchers at Oregon State University have had extensive experience in developing a forest-science data bank during the last decade. Long-term data sets are emphasized. Our experience suggests that: (1) documentation of methodology is typically weak, especially for long-term studies in which methods change over time; (2) accountability to a third party, such as a biometrician, improves documentation; (3) data sets need to be periodically analyzed--use invariably surfaces problems in documentation; and (4) data sets need to be archived in data depositories that offer uniform standards of data maintenance and make data retrieval possible and efficient. Art McKee will have some further observations on the virtues of careful documentation later in this symposium.

To summarize, scientists are going to have to learn to leave better tracks for future generations of scientists if their work is to have any value as a long-term baseline. Permanent and conspicuous but ecologically neutral field markings are important. Data archiving and documentation need extensive, continuous, and sometimes expensive attention.

ADOPT-A-NATURAL-AREA

Laissez faire management of natural areas is the third danger area. Simply the absence of management plans for most of the Federal research natural areas suggests that we have a serious problem. Such management as occurs is usually based on general agency guidelines (for example, the Forest Service manual), not on a detailed consideration of specific preserve objectives and the various factors affecting achievement of those objectives.

Developing specific objectives for every natural area is important. What are we trying to achieve? A lack of operational objectives often produces disagreements over management. Some individuals interpret the general guidelines as indicating that succession should be allowed to proceed, even when natural processes have been altered. Others interpret guidelines as a mandate for management to maintain a specific community or organism or to try to duplicate natural processes, such as wildfire, with management. Any or all of these approaches are allowable and may be appropriate on a specific research natural area--depending on the objectives of the particular area, however--which is why analysis of objectives is a key part of preparing a management plan. What do you want to achieve and in what part of the natural area?

Forest Service establishment reports are sometimes considered to be functional management plans, but I have yet to see an establishment report that even provides the detailed information base required to prepare a management plan. The Nature Conservancy is far ahead of the Federal agencies; stewardship plans have been developed for the majority of its preserves, and intensive management to achieve specific preservation objectives is characteristic of many of their properties.

We argue that the natural areas are invaluable, yet the management attention they are receiving is not consistent with those purported values. Management plans are a first step and can help clarify our objectives, as well as define management needs. They can also focus the attention of the busy local managers on these unique properties, identify neccessary investments, and serve as a basis for budgetary requests.

Finances are an additional issue that I will not dwell on here. Many of us are aware that research natural area programs, whether for management or research, are typically financial stepchildren. What is done is primarily through the good will of interested managers and researchers, not because of any institutionalized financial commitment to research natural areas. A lot of buck passing occurs in the area of financial responsibilities.

At least one aspect of stewardship is amenable to our efforts as individuals and small groups. Many natural areas have suffered simply because no interested or knowledgeable parties looked in upon them periodically. When people like Will Moir, Fred Hall, Chuck Wellner, and I have visited research natural areas in the course of preparing guidebooks, we frequently discovered that we were the first to visit them since establishment. Various activities occur that detract from natural area values--poaching for firewood, perhaps, or development of a hunter's camp. A timber sale may intrude because of incorrectly located boundaries. Overburdened agency management personnel are often unable to give the research natural areas the specific attention they deserve.

We could insure that our research natural areas do get regular and sympathetic attention if each of them was adopted by an interested individual or group. This program would at least provide for regular visits during which management problems and developments would be noted. Problems might include inappropriate use, and a development might be a storm that resulted in substantial tree mortality. The results of these visits could be documented, providing the managing agency with a continuing record of developments in the natural area and flagging developing problems before they become critical. The documents would also become part of the scientific record of the natural area.

As with management planning, The Nature Conservancy is ahead of the Federal agencies in volunteer involvement with management and use of natural areas. Many Nature Conservancy preserves have management committees composed of interested scientists and laypersons. These committees sometimes develop and implement the management plans, although many State and regional offices of The Nature Conservancy have

professional stewardship positions, and larger preserves have full-time directors and management staffs. Sometimes universities have assumed responsibility for management and protection of The Nature Conservancy reserves.

Stewardship is currently inadequate for most of our Federal research natural areas. Objectives are often poorly defined, detailed management plans are generally lacking, and funding is inadequate for dealing with a scientific resource that is truly invaluable. We must continually work to improve this situation, but we can take direct action now with an "adopt a natural area" program. As individual scientists, research work units, university departments, junior colleges, citizen groups, or whatever, we can insure that specific research natural areas receive regular visits and that a record of management activities and natural events is created and maintained.

CONCLUSIONS

My apologies to you for this Cassandraic keynote. What follows should be considerably more upbeat. The symposium will, I hope, help to stimulate baseline monitoring and research in the outstanding system of natural areas that we are creating through cooperative Federal, State, and private programs. We must never forget that creating the system is only the first step: eternal vigilance is, unfortunately, essential for a permanent system. The research natural area system needs to be actively managed and to be used for carefully documented research and monitoring. For each of us, a professional commitment above and beyond the scope of anyone's current job description is required--the future of our natural area system relies on philanthropy in the best sense of the word.

Section 1. Baseline Monitoring

BOTANICAL BASELINE MONITORING IN RESEARCH NATURAL AREAS IN OREGON AND WASHINGTON

Sarah E. Greene

ABSTRACT: With human impacts on more and more of the landscape, long-term, high-quality monitoring programs in natural ecosystems are increasingly important. Establishment of botanical monitoring systems in research natural areas in Oregon and Washington is providing baseline data used for (1) testing ecological hypotheses, (2) judging the effects of management activities on similar ecosystems, (3) understanding basic ecosystem processes, and (4) providing data on flora and fauna. Botanical monitoring systems need to be established and carefully referenced, with procedures rigidly defined.

INTRODUCTION

Gene Likens, past president of the Ecological Society of America, stated at the 1983 meeting of the American Institute for the Biological Sciences ". . . .that a major priority for ecology today is to establish long-term studies, including high-quality monitoring programs, in a variety of ecological systems throughout the world. Qualitative and quantitative observations over long periods are vital to formulate meaningful, testable hypotheses in ecology" (emphasis mine). Likens' concept of long-term monitoring studies necessitates research sites that are protected from manipulation where activities such as logging, farming, grazing, and industrial development are not allowed. Federal research natural areas (RNA's) provide these kinds of sites. Representing a wide array of terrestrial and aquatic ecosystems, RNA's are established as permanent study sites to be maintained in their natural condition, with baseline monitoring as a major research focus.

Baseline monitoring on RNA's is not a final objective, but rather a means to an end. Monitoring should provide high-quality data about the ecology of a species, ecology of the community in which it lives, and ecology of the system in which the community exists. Monitoring activities may have a current research objective as well as provide data for future analyses. Ultimately this data will allow the researcher to ask more meaningful questions, to test more viable hypotheses, and to better address the problems of understanding ecosystem processes. This, in turn, will help managers deal with the resource in a way that is more compatible with natural ecological processes.

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The Pacific Northwest (Oregon and Washington) research natural area program has been emphasizing botanical baseline monitoring for a number of years. Permanent sample plots established in 1947 at the Thorton T. Munger RNA in Washington are still being measured. In the last 10 years monitoring has become an increasingly important concept. The purpose of this paper is to discuss botanical monitoring--studies of long-term duration (greater than 5 years)--using examples from RNA's in Oregon and Washington. This includes a fairly broad range of plant-oriented studies--from floral surveys to mortality analyses. Four categories will be discussed: successional plots, floristic surveys, ecological processes, and classification plots.

SUCCESSIONAL PLOTS

Successional plots, in the form of permanent sample plots, are one part of our monitoring program. If monitoring is to be long term, then permanent installations must be established for consistency, statistical validity, and accuracy of data collection. Permanent sample plots may serve many purposes. In the Pacific Northwest RNA program they have been used primarily to look at growth and yield of stands and to monitor mortality. The program uses two major strategies for establishment of permanent sample plots. One type, called reference stands, can be located in selected plant communities, in a particular stage of succession, or in particular type of environment. The other type, circular plots, is used to systematically sample an area.

Reference stands are generally 1 to 2 ha in size. They are surveyed and marked every 50 m around the perimeter and in the center with plastic or aluminum pipe, and every 25 m with either cedar stakes or reinforcing bar (fig. 1). The entire hectare is then divided into a 5 by 5 m grid to facilitate tree tagging and mapping. Within the plot every tree, 5 cm diameter at breast height (d.b.h.) or greater, is tagged, measured for d.b.h., vigor coded, and stem mapped. Generally 20 to 30 trees, representing 20-cm diameter increments, are measured with an optical dendrometer, which provides information on height, volume, and surface area. All standing or down dead wood, greater than 15 cm diameter, is mapped for size and decay class.

Circular plots, 1 000 m^2, differ somewhat from reference stands (fig. 2). They are surveyed in the center and permanently marked both there and on the circumference at the four cardinal points. Four 12.5-m^2 seedling subplots are

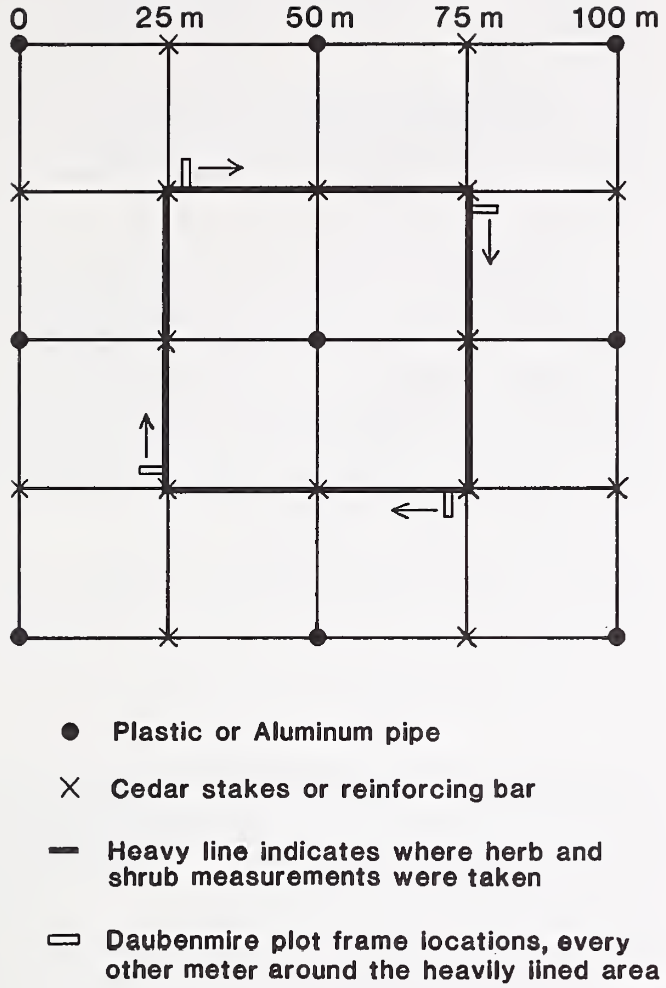

Figure 1.--Reference stand showing permanently marked points and the herb and shrub sampling line.

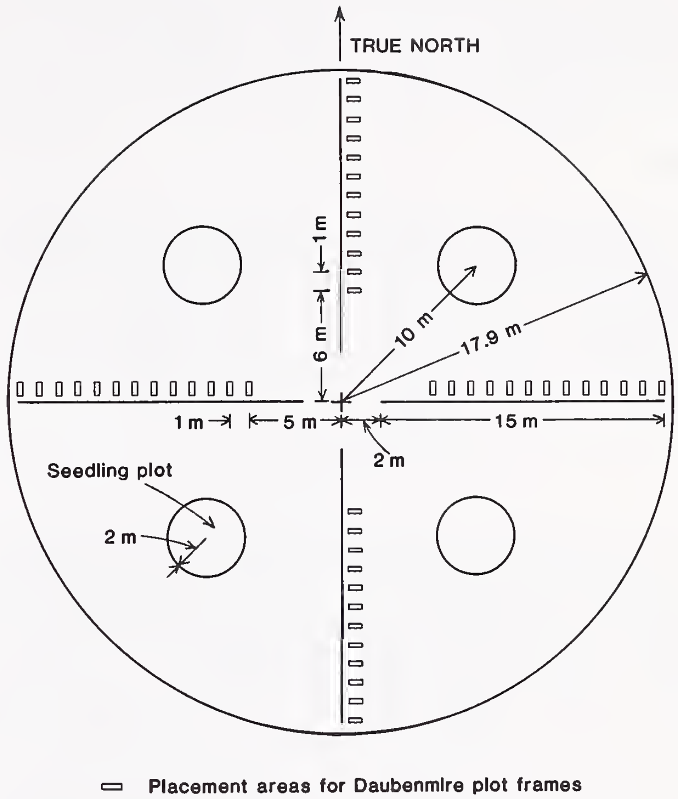

Figure 2.--Circular plot showing center point, seedling plots, and the herb and shrub sampling line.

located 10 m from the plot center. Seedling subplot centers are marked with reinforcing bar. Trees are tagged, measured, and vigor coded. Trees and dead wood are not mapped.

In most cases, herb and shrub vegetation are subsampled in permanent sample plots. The techniques vary. For reference stands a Daubenmire plot frame (20 by 50 cm) is used to measure herb cover. At alternating meters along 200 m of transect (fig. 1) the frame is laid down facing toward the outside of the reference stand. On circular plots the plot frame is laid down at points along four radii emanating from the center in the four cardinal directions (fig. 2). Shrub cover is measured by using the line intercept method along the same transect lines as for the herbs.

Tree mortality checks are made on an annual basis to determine timing and cause of mortality. Every tree in a plot is visited, checked to see if it is dead or alive, and, if dead, measured for d.b.h. and coded for cause of mortality. Tree remeasurements are done approximately every 5 years. Understory vegetation is not ordinarily remeasured unless there is some reason to do so, such as after a wildfire, bug infestation, or mudflow.

All data from permanent sample plots are entered into a micro-computer and stored in the Forest Science Department Data Bank, Oregon State University, Corvallis. Permanent ink maps of the stands have been drawn by hand in the past. Recently a micro-computer program was written that will produce a stem map. A program is currently being developed to map dead wood.

Location of reference stands is a subjective process. Generally an attempt is made to locate the permanent sample plot in a representative stand of a particular forest type or successional stage. Location of circular plots is usually more systematic with plots laid out at regular intervals along transect lines. In some cases a series of transect lines may create a systematic grid of plots. Transect lines may also be oriented to sample across environmental gradients and ecotones.

Because both kinds of plots are permanently marked in the field and are well documented, many other kinds of long-term studies can capitalize on their presence. Mammal population dynamics, insect collections, litter decomposition, biomass sampling, growth and yield of forest stands, nutrient cycling, forest

meteorology, accumulation of heavy metals, and disturbance patterns are some examples of studies that have been done on these plots. The existence of these permanent sample plots also makes data collection by other researchers more cost effective.

As of March 1984 there were 33 ha of reference stands and 250 circular plots, representing 14 different forest types on 15 out of 96 established RNA's in Oregon and Washington.

FLORAL SURVEYS

A floral survey is one of the most basic kinds of botanical monitoring. It can be used both to determine the presence of rare, threatened or endangered species and to get a thorough inventory of plant species, their habitat, and abundance. Until this is done, it is nearly impossible to determine whether changes in individual plant populations or floral compositions are taking place.

Floral surveys can be very time consuming and can differ widely in their usefulness. Fourteen floral surveys have been conducted on RNA's in the Pacific Northwest. Six of these surveys have been published by the Pacific Northwest Forest and Range Experiment Station[1/] (Mitchell 1979, Schuller 1981).

For these six surveys each area was visited 7-10 times, depending on size and accessibility, during the growing season. On the first visit a walk through the area was done to determine the range of habitats. The RNA was then stratified and described in units that would be recognizable in the future. The number of units depended on the size of the RNA and habitat heterogeneity. On successive visits all habitats within the various units were surveyed on at least one occasion. Special attention was paid to small-scale, unmappable anomalies, such as rock outcrops, seeps, and small ponds, as these areas tend to harbor a large variety of species.

When reliable identification of species could not be made in the field, unknown taxa were collected, taken to the lab, keyed, compared with voucher specimens, and identified. Most specimens collected in the field were deposited in an herbarium. Location and habitat descriptions were included. Herbaria especially welcome specimens from RNA's because RNA's serve as permanent reference areas.

The survey publications include information on the environment and habitat or community types of the RNA surveyed. The checklist in each one includes family, genus, and species, as well as the habitats where the plants were found.

Floral surveys are often somewhat subjective. Those doing such surveys should be familiar with the flora of the region and have a feel for habitat variation, especially if the approach to sampling is nonquantitative.

ECOLOGICAL PROCESSES

Most ecological processes exhibit a lot of yearly variability (Likens 1983). Long-term records are needed to clearly understand these processes. Numerous examples exist where extrapolation drawn from two to three years of data have led to the wrong conclusions. RNA's in Oregon and Washington have provided opportunities for monitoring some ecological processes with the use of permanent sample plots, cone plots, and seed and litterfall traps.

Five RNA's have a continuous record of cone crops for periods ranging from 5 to 17 years. These plots were established where 15 to 20 tree tops could be easily detected from a trail or road. Trees were numbered with tree paint and mapped from the road or trail using a compass. Cone counts on all trees are made each year from the same spot and direction, with the help of a spotting scope. Continuous records such as these are useful in predicting cone crop periodicity and understanding the dynamics of one part of the stand regeneration process.

Tree seed has been collected for 20 years from two RNA's, one in Oregon and one in Washington, to extend our understanding of regeneration. The traps are 20 by 50 cm wooden frames with wire bottoms. Nylon mesh liners are placed on top to intercept the seed. Six to 8 traps are spaced at 10 m intervals on the forest floor.

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Schuller, S. Reid; Cornelius, Lynn C. Checklist of the vascular plants of Goat Marsh Research Natural Area. Adm. Rept. PNW-3. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Forest and Range Experiment Station; 1982. 18 p.

The liners are collected during midsummer and after spring snowmelt. The seed is sorted according to species and is counted and tested for viability.

A litterfall study of anthropogenic substances has been under way by Batelle Northwest Laboratories for nearly 7 years on four RNA's in the Pacific Northwest. Monthly samples of litter are collected from permanent collection buckets installed at each site. The litter is analyzed for nutrient content to determine the amount and kinds of airborne pollutants being intercepted by tree canopies.

A study that uses litterfall to index primary productivity on an annual basis is taking place at Wildcat Mountain RNA in Oregon. For 7 years litter has been collected from six 1 m^2 traps systematically located in the forest stand. The samples continue to be collected, and are first sorted according to twig, leaf, bark and branch, then oven dried, weighed, and archived.

VEGETATION CLASSIFICATION PLOTS

It is the responsibility of the area ecology program in Oregon and Washington to provide the National Forests with a plant community classification and predictions of site productivity. Included are the establishment of permanent photo points and sample plots that can be revisited at regular intervals. Because much of the forest is slated for future harvest cutting of some type, RNA's are among the few areas where permanent sample plots and photo points can be protected. At least 20 RNA's have been used by the area ecologists for the establishment of 30 permanent plots in 24 forest types.

Plots are established within specific habitat types. They are marked permanently in the field, on air photos, and on topographic maps. Measurements of site productivity, of wildlife use, and of basal area by species are taken. Soil descriptions and a stand density index are also included. Permanent photo points are established, and all information is entered in the Forest Service Total Resource Inventory System.

These plots provide practical information for use by the Forest Service. They also yield much data that can be used by the research and academic communities.

PROBLEMS

Establishing and monitoring permanent sample plots is only the beginning. The field work is often the fun part, but if it is not followed up by careful referencing, data organization, and some financial support the process can easily become stymied. As in any research study, objectives must be clearly defined before the study begins. One must know what and why one is measuring and monitoring. Each plot location must be well marked in the field and documented in some kind of report in the office. Procedures for data collection must be rigidly and clearly defined, so someone 40 to 50 years from now can know exactly what, how, and where things have been done. The large volume of data generated must be carefully organized. Continuous records must be maintained, updated, entered into the computer, verified, and analyzed. The data need frequent analysis in order to detect inconsistencies, omissions, and problems.

Botanical baseline monitoring takes time, money, and people. Convincing managers, directors, rangers, supervisors, and program coordinators that this kind of work is worthwhile can itself be a large task. One of the best ways is to make sure that the benefits of monitoring programs are known to the scientific community and to managers. Nothing is more convincing than actual use of such programs and the data they provide.

In the Pacific Northwest scientists have just begun to gather baseline data on RNA's. Ninety-five percent of the monitoring programs are west of the Cascade Range, and 99 percent of these are in forested stands. Botanical baseline monitoring programs are also needed for thousands of acres of shrub-steppe, desert, and other nonforest vegetation in RNA's.

CONCLUSIONS

Baseline data collection is often viewed as merely descriptive or as number gathering with no purpose in mind. Presently the huge natural landscape of the west is being altered by a resource management that tends to significantly change the natural world. As this is happening it becomes more and more important to know what is being lost, and to understand the patterns and processes of a rapidly diminishing natural landscape. In the face of these changes, baseline monitoring becomes all the more important.

Well-documented baseline monitoring should be a long-term goal. We need to have well organized and related sets of data that identify ecosystem components and how they function. This is especially true for ecosystems that have not yet been altered by management activities. This is not to say that short-term projects are not important; rather, such projects should be interactive with a long-term goal--understanding and documenting the baseline.

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LONG-TERM MONITORING OF SMALL VERTEBRATES: A REVIEW WITH SUGGESTIONS

Curtis H. Halvorson

ABSTRACT: Vertebrate monitoring should consist of following long-term ($\geq$ 10 yrs) patterns of relative abundance and distribution. Examples of long-term study reveal natural population variability and deficiencies in short-term study. Index methods that express animal abundance relatively, and as detections per unit measure, are suitable and outlined. Recent experience suggests that combinations of methods can be very effective for herptiles (amphibians and reptiles) and small mammals. Rodent populations should be monitored to cover annual high and low levels, and unconventional techniques should be considered. Biases are different in determining bird abundance than for other vertebrates. Recent monitoring literature is reviewed, and the mistake of assuming animal presence to represent animal needs is discussed. Monitoring plans should relate to the expected frequency of natural events, with accessory information and pilot study necessarily included. Information needs are suggested.

INTRODUCTION

Monitoring is a temporal procedure for collecting information. A baseline is the thing we measure differences or changes against; and change, according to Lund (1983), is movement of an object over time. The movement could be the rate of root penetration by a ponderosa pine seedling, abundance and reproductive success of peregrine falcons over time, or board foot increase in a forest to rotation age.

Our concept of monitoring depends on why we do it. If we monitor where people practice husbandry or resource management, then monitoring is tracking the stock on hand for a chosen objective. Then we monitor to know when we have achieved, or perhaps overachieved. This contemporary concept has been expressed in a general, a social (Bell and Atterbury 1983:664;227), and a biological (Salwasser and others 1983) context. By contrast, monitoring on a research natural area (RNA) requires that natural processes dominate; we do not instigate change and we seldom use the feedback to fine tune our actions. The definition of monitoring Franklin and others (1972) applied to natural areas was "...observing change in some aspect of the ecosystem over a period of time." That definition suggests a more passive activity - measuring bog progression or counting bird numbers and species.

I will talk about efforts that document the distribution and relative abundance of vertebrates. This follows the natural area monitoring definition. Natural fluctuations occur in all organisms but we seldom pursue our monitoring of wildlife long enough to know what the baseline is, i.e., if the variation associated with disturbance is within or beyond standard deviations of natural change. I present examples of "normal" variation in animal numbers, then outline methods to assess change and considerations in applying them, and finish with suggestions for needed information. Important elements of monitoring in natural areas include using the simplest applicable methods, a commitment to careful documentation and long-term continuity, and incorporating some complementing environmental information into the process.

Fourteen years have passed since enactment of the National Environmental Policy Act (NEPA, PL 91-90) - a progenitor of our mandate (Salwasser and others 1983) to assess, appraise, inventory, monitor, and report on our natural resources. Recently the proceedings of two international resource conferences were published: a session of six papers in the 48th North American and Natural Resource Conference, and 182 papers at an Oregon meeting (Bell and Atterbury 1983). These conferences dealt with inventories and monitoring in managed habitats (disturbed ecosystems), i.e., the feedback type of monitoring. They reflected that we are at the stage of describing our maturing experience with monitoring. Many studies were quite recent and represent appraisal and reappraisal (Hinds 1983; Hirst 1983; Raphael and Rosenberg 1983; West 1983). Two earlier papers (Hilborn and Walters 1981; Romesburg 1981) are critical of our science and worthy of reading prior to embarking on monitoring and assessment programs.

The terms modeling and multiresource inventory were emphasized in many papers. Romesburg (1981) defines modeling as an informed guess, a mixture of knowledge and error, about a process of nature. Among modelers there are five or six kinds, not all with standardized labels (see Hirst 1983; States and others 1978:B-38-39). Two broad categories exist: the deterministic or analytical model based on known or accurately

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described elements; and the simulation, stochastic, or predictive model that mimics a real system and draws heavily on assumed or hypothesized relationships. The deterministic model gives indirect but accurate answers. The simulation model gives direct but inaccurate answers (Romesburg 1981; Hirst 1983). Many of the conference papers focused on multiresource (i.e., multispecies) inventory (see Davis 1983). Modeling proposals and efforts associated with multiresource study (Bell and Atterbury 1983) relied heavily on assumed dependencies based on species-habitat associations, rather than experimentally derived determination of actual dependencies. A preoccupation with simulation modeling does not appear to lend itself to accountability down the road. We may be obscuring the point that predictive models are only planning tools, not scientific evidence per se. These distinctions are seldom clarified. A remark attributed to Frank Egler (Jenkins 1977) was: "Ecosystems are not only more complex than we think, they are more complex than we can think." We can become swamped with untested hypotheses and decision makers may be attracted to increasingly elaborate and expensive predictive tools that could be masking truth. Models are often based on short-term studies that only identify associations. Wagner (1974:1492) states"...my concern [is] that the risks of incongruence between models and reality grow as the former becomes increasingly abstract. Hence, we need to maintain vigilance based on solid empirical foundations while at the same time pressing forward with analytical efforts...".

EXAMPLES OF LONG-TERM MONITORING

We monitor a system to learn of patterns; to recognize long- and short-term trends and marked deviations from norms. Perhaps the longest term monitoring efforts on vertebrates are found in human demographic records — the vital statistics listing births and age at death.

The data on natural variation obtained from baseline monitoring can be seen in selected examples of long-term (>5 years) tracking studies. The examples show that the 1- to 3-year efforts typical of our inventory and appraisal programs seldom bracket the natural range of variation in species composition and abundance, rarely document extremes, and can hardly verify patterns. The duration of monitoring should encompass the natural variation in the organisms or system under study.

1. Animal communities are not static and they vary in both numbers and species.
   a. There was a 23-fold difference between peak and low numbers in snowshoe hares (*Lepus americanus*) during a 15-year study (Fig. 1) and a 13-fold increase in deer mice (*Peromyscus* sp.) over 2 years in a Michigan hardwood forest (Sexton and others 1982).
   b. During a 17-year monitoring of small mammals, using the simplest method (20-station kill-trap lines), seven species were caught in 1 year, one was caught in 1 year, and either three or four were taken in 11 years. Variation in species diversity can be large in simple severe habitats such as the salt desert shrub location of this study (Reid, unpublished)[1].
   c. The highest population growth rates and densities in a red-backed vole (*Clethrionomys rutilus*) study did not show up until years 10 and 12 (Mihok and Fuller 1981).

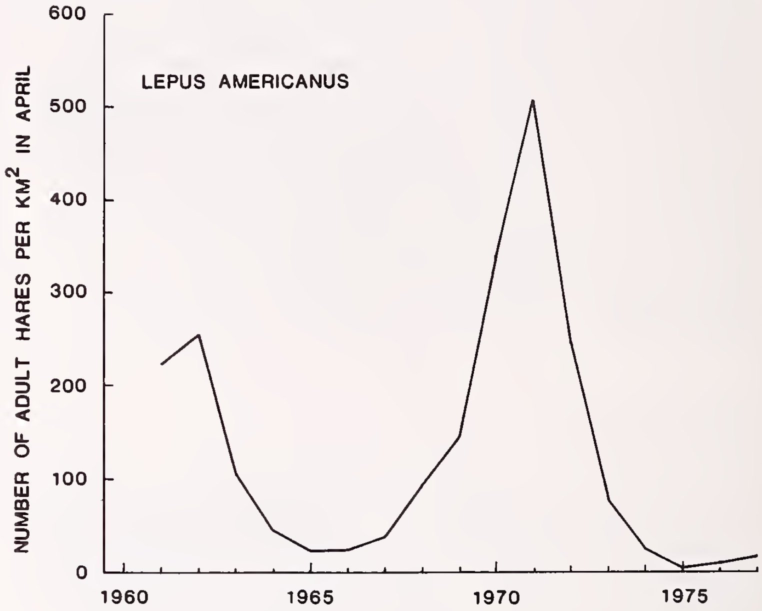

Figure 1.-- Cyclic fluctation in snowshoe hares (*Lepus americanus*) in Alberta, Canada (Keith 1983).

2. We are often misled about animal communities if we only sample in 1 or 2 years.
   a. In an uncut forest (Fig. 2-A), a vole (*Clethrionomys gapperi*), a mouse (*Peromyscus maniculatus*), and a chipmunk (*Eutamius ruficaudus*) had different levels of abundance in two pairs of years. In 1969-70 their respective proportions in the catch were 75%, 4%, and 18% while in 1973-74 they were 10%, 30%, and 52%, respectively (Halvorson 1982, and unpublished). It is understandable why apparently similar studies often disagree and many wildlife-habitat associations studies can be unreliable indicators. Yet any year of the eight studied on a clearcut burn was consistent with *Peromyscus* dominance (Fig. 2-B).

[1] Reid, V.H., Ft. Collins, Colorado: Data on file at Denver Wildl. Res. Ctr. Field Station, U.S. Fish and Wildl. Serv.

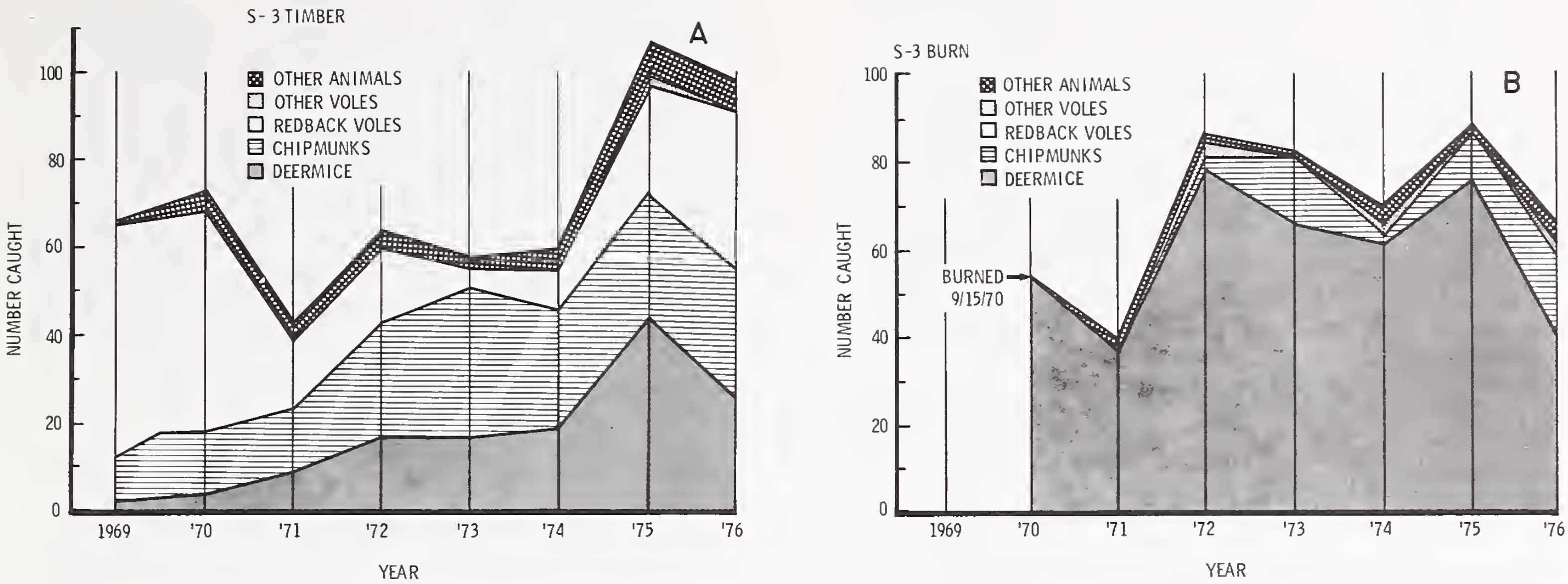

Figure 2.--Two examples of species relative abundance illustrate typical variation that can occur between years on the same plot: A) large variation in a north aspect uncut larch-fir forest; B) little change on a thoroughly burned, south aspect larch-fir clearcut (Halvorson 1982 and unpublished).

3. The ability to recognize patterns can only come from extended monitoring.
   a. An English study of species-habitat associations was conducted for 20 years (Southern 1979). Two rodent species averaged 20 per ha and fluctuated regularly about a mean.
4. Habitat-wildlife associations may not be apparent until a trend in abundance is obtained.
   a. The Canadian breeding bird survey showed a 10-year decline in five bird species that are normally associated with woodland edge and seral vegetation stages. The surveys were made in an area where agricultural land was reverting back to a closed forest canopy. An increase in red-winged black bird numbers was accompanied by increased corn acreage and a behavioral shift by birds from marsh to upland nesting in response to wetland drainage (Erskine 1978).

5. Natural events must be allowed to fully occur, especially if extrinsic factors are implicated.
   a. It took 15 years to observe 1.5 cycles in snowshoe hare abundance, or one increase and two declines (Fig. 1).
   b. Because tree seed crops are not predictable or necessarily in synchrony, it took 12 years for crop failures and abundance to be repeated by two conifer species, allowing comparisons to be made with red squirrel (Tamiasciurus hudsonicus) population fluctuations (Fig. 3; Halvorson, unpublished)[2].
   c. Red-spotted newts (Notopthalmus viridescens) breed in ponds but their young leave to mature on land. Fidelity to their birthplace is the fashion of salamanders, as for birds, eels, and salmon. After 6 years none of 800 marked newts showed up and were presumed lost, however in the seventh year and beyond, marked newts appeared. The biologist found these newts don't sexually mature for 4-8 years (Likens 1983).

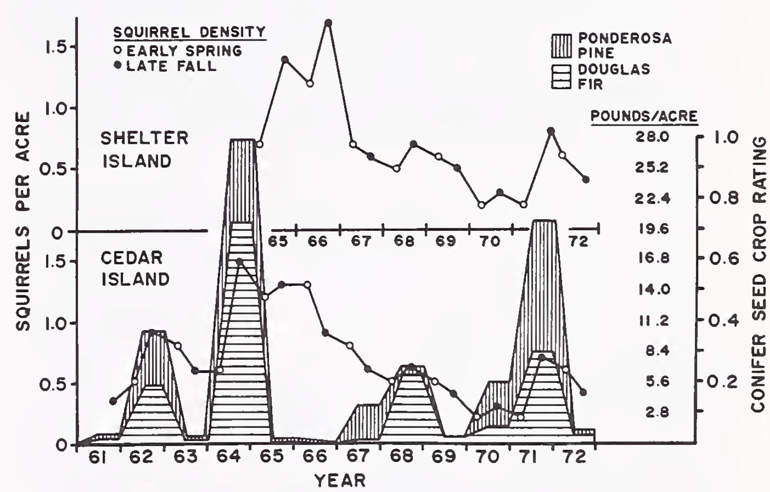

Figure 3.--Abundance patterns in two components of a Montana forest ecosystem-the red squirrel (Tamiasciurus hudsonicus) and seed crops of two conifer species - over time (C.H. Halvorson, unpublished).

[2] Halvorson, C.H., Ft. Collins, Colorado. On file at Denver Wildl. Res. Ctr. Field Station, U.S. Fish and Wildl. Serv.

DESIGN AND SOME CURRENT EFFORTS IN BASELINE MONITORING

Four design elements are essential to an ecological monitoring program (Hinds 1983; Hirst 1983; Likens 1983; Stankey and others 1983; Verner 1983): (1) long-term to bracket variability, (2) statistically valid and sensitive to trends, (3) cost effective, and (4) ecologically appropriate. Monitoring in a RNA is not a short-term tactic calculated to solve a temporary problem; it is a long-term strategy. Unlike monitoring in impacted areas, the time-frame for discerning trends and change in an RNA need not be artifically confined to a fixed pretreatment period that restrains data analysis to that available at the scheduled end-point, often a brief 1-3 years. Likens (1983) identified monitoring as a continuing objective whose overall purpose is to learn enough about systems to formulate meaningful and falsifiable questions. The inventory of patterns developed by long-term monitoring is capital gain. Statistical considerations center on detecting and comparing change over time, and deal with adequate replication. sample sizes, and stratification. Nonparametric analyses are often more appropriate. Mihok and Fuller (1981:2277) used such tests on vole fluctuations, based on catch per unit effort using kill-trap lines. Nowadays design can have legal implications if an economic or esthetic resource is concerned. RNA's can also serve as natural controls in the experimental design of monitoring programs, though routine monitoring can be a valuable part of ongoing management (Hilborn and Walters 1981). Good monitoring design relates sampling frequency to animal life history; i.e., ground squirrels are above ground only 4 months of the year and herptiles may be especially active after rainstorms. Dawson (1981a) covers factors to be considered in bird counting.

Cost effectiveness often influences study design through budget-partitioning decisions to accomplish goals (see Verner 1983). Costs become critical in proportion to the imperative for minimizing uncertainty of a prediction (Salwasser and others 1983). Great Blue Heron nesting garbage was finally selected as the estimator for environmental contaminants after a very structured search for the most efficient method (Carlile and Fitzner 1983). If natural area monitoring is mostly a continuing program that emphasizes species inventories and population trends, then the decision risk is low, and permits simple, frugal techniques. Raphael and Rosenberg (1983) reported on cost-effectiveness of six methods to inventory forest biota. Live trap grids were the most costly, at $45.00 per sample plot per species detected. Variable circular bird census plots were the most cost-efficient at $2.00 per plot per species detected. Abundance determinations, as opposed to simple detections, raised costs proportionately. Pitfall traps were singularly efficient ($8.65) in taking shrews, moles, herptiles, and uncommon mice. Baited, sooty, tracking plates ($7.54 per detected species) recorded nine species not otherwise recognized. The impact of destructive versus benign methods (litter search vs. pitfalls for amphibians) should be considered. The relative costs of detecting common versus rare species is analyzed by Marcot and others (1983). Verner's (1983) cost-effective decision was to monitor birds because they were the most conspicuous vertebrate, and to search only at a level necessary to detect decline because increases were not of management concern. As a next step, he advocated that the most cost-effective monitoring could be obtained by substituting trends in habitat condition diversity for direct species monitoring. A feedback loop would eventually reinforce the knowledge of species habitat needs such that habitat alone would reflect species status. A related assumption was that the stability of birds, grouped by management guilds in sensitive habitats (riparian, meadow edges, mixed conifer), would reflect the stability of other taxa, e.g., mammals and herptiles.

Questions arise as to these proposals. My personal concern is an uneasiness with a prevalent mind set on multiresource monitoring. This keeps repeating and confusing wildlife-habitat associations with wildlife species needs. "...A near universal premise of the models (wildlife-habitat relationships) is that the distribution and abundance of wildlife species may be presumed from habitat components" (Marcot and others 1983). To assume that tracking bird population trends will signify to us which way entirely different classes of organisms will go is a magnificent presumption in light of our present scanty knowledge of an animal's specific critical needs.

The fourth design element, ecological appropriateness (Hinds 1983), requires that our assumptions about ecological relationships be valid. Confusing species associations for dependencies was implied or expressed in many of the symposium papers (Bell and Atterbury 1983). Recognition of the difference was rare. Therefore, it seems we are still very much in a state of perceived rather than proven relationships between a species and where it occurs. Yet perceived relationships are the basis of our Habitat Models (O'Neil and Schamberger 1983). According to Paine (1981) many, if not most, fundamental interactions between a species and its environment are nonlinear and the exercise of some free choice by mobile species adds "noise" (i.e., can confuse predictive models trying to relate to the real world).

The conferences of 1983 reported recent efforts or plans to relate wildlife species abundance to habitat features. Attempts to link Forest Inventory Surveys and wildlife resource assessment were described, but the findings were inconclusive. Morrison (1983) decided that more habitat variables were necessary, beyond the 13 he used to predict timber growth and volume, because those left 65-85% of variation

unexplained. Yet when 270 timber and habitat descriptors were measured (Porter and others 1983), 90% of the variance was accounted for in 10% of the factors. Replicated year sampling was advised. A study evaluating HSI's (Habitat Suitability Indices) to monitor wildlife only measured two variables (cover and height) of three floral life forms in a 3-month study. The results were inconclusive and another study covering at least 2 years was suggested (Cole and Smith 1983). A 2-year progress report (Raphael and Rosenberg 1983) on multiresource inventory had two dissimilar years of bird inventory data and concluded that there is no surrogate for long-term replicated study.

Short-term, one- or two-season, multiresource inventories usually monitor easily measured physical variables from which sophisticated predictions are made, but temporal variability is certainly a characteristic of vertebrate populations. The species-specific sampling techniques of Raphael and Rosenberg (1983) gave positive results and indicate the effectiveness of incorporating behavior. Managers will not recognize the consequence of their decisions if they are led to believe an animal's function and address are the same. The interactions between animals, their food, space, competition, and behavior do need far more delineation before mathematical relationships with habitat variables can be assumed or achieved (Pielou 1981). Studies reported at the meetings discussed above recognized that fact to varying degrees.

For very common species it is possible to accurately predict their presence, or even their abundance, from secondary indicators such as vegetation type or structure. But rare creatures are much more sensitive to limitations in their environments and we need precise knowledge, beyond an association, of their needs (Jenkins 1977).

Finally, requirements for good design can sometimes be met empirically. Eighty ha (200 acres) of ponderosa pine, among many thousands on a certain Wyoming mountain, serve as a winter roost for two eagle species. Explaining the use of that special 80 ha is "...a prairie hunting ground, well grazed and normally blown clean from stormy westerly winds, with a river close by covered with ponderosa pine for roosting, where there is an evening updraft to an undisturbed ridge that slopes westward toward the hunting country" (Kerr and Brown 1977) -- allowing an energy-efficient glide to breakfast the next morning.

But this explanation has not been tested, therefore is only conjecture without a probability statement. It does represent a synthesis of careful and prolonged observation by curious people who were interested in eagles and could conceive of relationships because they had lived and worked amidst natural interactions a long time. What single element or minimum combination makes eagles use that 80 ha? Logic and truth are not synonymous and proving the hypothesis might not be worth the cost, even if testing were possible. We can't divert the prevailing winds and clear-cutting the west rim could not be worth validating a prediction, but the process by which the Jackson Canyon eagle presence is explained should also be considered a valid, and cost-effective, and ecologically appropriate design for monitoring. Observational design is also appropriate for studies in research natural areas.

METHODOLOGY

Monitoring in research natural areas versus managed lands differs chiefly in the application of findings rather than in the methods used. We rely on the same pool of techniques for estimating wildlife populations.

I will cite several recent references that represent major literature searches. Some are relatively inexpensive or available as agency publications. There are also excellent accounts on regional species' biology (e.g., Maser and others 1981).

A broad scope of methodologies for vertebrates is found in Schemnitz (1980), Call (1981), Miller and Gunn (1981), and States and others (1978). Davis' (1982) book is a unique (but very expensive) collation of various workers' recommendations. It is based on their published studies and is both species- and habitat-specific, with discussions of over 100 species. Small mammal study is comprehensively treated by Golley and others (1975). Herptiles are covered in Scott (1982) and some of the previously mentioned works. The most recent complete coverage on birds is edited by Ralph and Scott (1981). Short papers by Mannan and Meslow (1981) and Martinka and Swenson (1981) give concise evaluations of counting methods for nongame and upland game birds, respectively. Call (1978) on raptor surveys, Franzreb (1977) on general bird inventorying, and Mikol (1980) on field application of bird transects are useful. Publications that integrate habitat with wildlife include U.S.D.I. Fish and Wildlife Service (1977), Flood and others (1977), and Short and Burnham (1982). Progress towards an ecological land classification is reported by Driscoll and others (1983). Caughley (1977) treats the analysis of population data as do articles in Ralph and Scott (1981) for birds. Finally, Delaney (1974) summarizes methods, results, and opportunities for small mammal ecological study.

The uncertainty of choosing the correct method to determine species abundance in a research natural area is diminished by knowing there is no correct method for birds, mammals, or herptiles. A "wrong" approach would be selecting an unnecessarily precise and expensive procedure. However, if a rationale is needed for selecting a census method, Garton (1981) shows a dichotomous procedure, based on critical questions about the populations. Absolute density estimates (individuals per unit of area)

are necessary in certain ecological studies (e.g. food chain or contaminant energetics, disease transmissions), but are seldom needed for baseline inventory. A complete count of any wild population has rarely been achieved. The density figures presented in literature are often derived estimates based on violated assumptions. To compare between populations or between years, an index of relative abundance, numbers caught per se, or catch, sight, or sign per unit effort is felt to be as meaningful, but more economical, as correlates of density (Caughley 1977:12; Mannan and Melsow 1981; Dawson 1981 b,c; Emlen 1981).

Amphibians And Reptiles

Herptiles are suitable but neglected candidates to monitor because they often have limited movement, strong fidelity to shelter and breeding sites, and can be sensitive to environmental changes. Their abundance is quickly enhanced by a rain, offering opportunistic options for detection with the proper conditions. Their ecosystem relationships are not well known (States and others 1978), but they can be an abundant segment of forest fauna (Scott 1982). Bury and Raphael (1983) report 400 to 3,000 salamanders per hectare. The behavior of herptiles can also make abundance estimates difficult. They are secretive, frequently nocturnal, well camouflaged, often swift, fossorial, and seasonally or geographically inactive for long periods (Heatwole 1982). Small mammals have similar characteristics.

Proven experience with a combination of old and new censusing methods is succinctly explained by Bury and Raphael (1983). Results are available from Pacific Northwest old-growth conifer forests (Raphael and Rosenberg 1983), mesic and upland Florida habitats (Campbell and Christman 1982), and deciduous forest and field environments in Wisconsin (Vogt and Hine 1982). These studies used pitfall and funnel traps with drift fences to channel animal travel. Pitfalls were particularly efficient for herptiles and also for certain rodents and shrews (Raphael and Rosenberg 1983; Williams and Braun 1983; R. Bury, pers. comm.). Pitfall trapping, if used as a removal sampling method, has potential for altering population structure because it is very efficient. Herptiles are usually long-lived and have limited home ranges. The best method of inventorying, according to Bury and Raphael (1983) utilizes pitfall arrays in combination with physical search methods. Results can be expressed as capture rates per plot searched, number caught per day or per unit length of drift fence (Vogt and Hine 1982), or biomass. Extrapolation of biomass is cautiously advised because herptiles commonly show clustered distribution. The minimum area needed to conduct searches and inventory depends on the species. For example, terrestrial salamanders usually occupy small home areas ($<100m^2$), but migratory forms may travel >1 km to breeding ponds. The overall size of herptile plots can often be a fraction of standard-sized bird or mammal areas. Most herpetological studies center on plots of 1-5 ha.

Mammals

Baseline monitoring of small mammals usually entails direct counts, such as by trapping. Trapping allows access to sex, age, and reproductive status of populations. Some direct count methods, night-lighting for lagomorphs or ferrets, can only show numbers observed. Direct count expressions of abundance can be numbers of individuals or captures per unit effort (catch per 100 trap-nights), with biomass a secondary but integrating figure. Indirect counts of sign sometimes may be the best available technique. Ungulate or rabbit pellet groups and coyote scat or scent station visits (Griffith and others 1981) are compared as sign per plot or distance travelled.

Relative abundance for the fossorial pocket gopher (Geomyiidae) can be compared with indirect counts (Reid and others 1966; Anthony and Barnes 1982). I have used indirect counts based on 0.05 ha (0.12 a) circular plots. Pocket gopher mounds are flattened and 48 hr later any new digging evidence is counted as an active plot. Relative density is expressed as the number or percent of plots having sign. Plots are spaced at 15.2 m (50 ft) along a transect, the distance reasonably assumed to separate individuals. Plot area should represent 5% of the site at minimum. Sampling is best done when activity is high, usually in late summer when young are forced from the parental burrow and are establishing their own tunnel system.

Small mammal monitoring with traps is particularly dependent on animal behavior - the sample coming to the collector. An index line of traps is the simplest, most meaningful and economical approach to long-term monitoring for comparing differences in numbers between seasons and areas (Linn 1963; Linn and Downton 1975; Southern 1965; Petticrew and Sadleir 1970). Index lines, circles, or groups of trap clusters (Hansson 1967; Peterle and Giles 1964) provide not only the minimal inventory information such as relative species occurrence, but also long-term abundance and reproductive patterns (Mihok and Fuller 1981). The results depend on how intensively the effort is applied and whether live or kill traps are used. Index lines, in tests against grid-determined density estimates, have produced sufficiently precise results to warrant their use as a convenient substitute. If used in conjunction with assessment lines, comparable and reliable density estimates have been obtained (Petticrew and Sadleir 1970; Smith and others 1975; O'Farrell and others 1977; O'Farrell and Austin 1978). A common index line configuration uses 20 stations per line, with stations 10-15 m (33-50 ft.) apart, and two to four traps placed within arm's length of each station point. A shorter spacing of 5 m (16 ft) is often used for voles. Bock and Bock (1983) advise paired lines but Whiting and others (1983) used 3 transects

per sample unit. Linn (1963; pers. comm.) used a short dense arrangement of 50 live traps in 10 clusters of five traps spaced 5 m apart. The lines were only 45 m (148 ft) in length and operated for a single 24-hr period, the rationale being to extract a time-specific sample before any population changes occurred. Southern (1973) also used a 24-hr period but with a grid and dense trap clusters. A 24-hr period attempts to fulfill the assumptions of closure, i.e., no birth, deaths, or movements in or out of the population. Some rodents, particularly young, travel in pairs, and if not caught simultaneously (Feldhammer 1977; Jenkins and Llewellyn 1981) in the same trap, there must be provision for same station capture. Several traps per station are normally used to minimize overload and biased sampling. Hansson (1967) advised 5 to 10 traps per station. If ≤80% of traps were occupied, Southern (1973) felt he had an adequate number.

The choice of trap type, live or kill, has ramifications. Heterogeneity in catchability can be associated with species and age (Jolly and Dickson 1983). Suggested compensatory procedures include using combinations of live, kill, and pitfall traps (Peterle and Giles 1964; Beacham and Krebs 1980; Raphael and Rosenberg 1983; Williams and Braun 1983); extended trapping periods; and experimenting with baits (Beer 1964; Patric 1970; Sullivan and Sullivan 1980). Peanut butter mixed with rolled oats has been a standard bait, effective for most situations. It is a common and useful practice to also include whole oats or sunflower seeds, particularly if voles are present. Their survival (in live traps) will be enhanced. For kill-trapping, usually two Museum Special mouse traps and one rat trap are set per station. Pitfall traps will probably be increasingly incorporated because of their efficiency (Beacham and Krebs 1980), despite greater cost to install (Raphael and Rosenberg 1983). Kill-traps operated no more than three consecutive 24-hr periods will reduce opportunities for animals nonresident to the line's area of effect from being drawn in as residents are removed (Southern 1973; Johnson and Keller 1983a). The actual area a snap-trap line affects remains in question (Johnson and Keller 1983b). Yang and others (1970) explored the problem on two vole species without reaching a conclusion and few studies have been done since. It has been conventional wisdom that kill-trapping once or twice a year for short (3 days) periods could have little impact on highly fecund rodents. However, there has been concern (L. Metzgar, pers. comm.) and evidence (Metzgar 1971; Mihok 1979; Webster and Brooks 1981; Clulow and others 1982; Jannet 1982) that some rodents have a well-developed social structure such that removal, especially of important reproductive members of a population, can alter subsequent breeding patterns, age structure, and behavior among young and females (Van Horne 1981).

The question of snap-trapping repeatedly in the same areas is not resolved, but the most complete and rapid determination of population patterns comes from live-trapping that is repeated during high and low periods of an annual cycle, as West (1982) did on the red-backed vole (C. rutilus). Otherwise, with once per year trapping a minimum or maximum can only be assumed, not identified. To do repeated trapping, in light of the previous consideration, I suggest live-trap index lines or trap-groupings applied during a breeding period, usually the low point and in spring, and again during the post-breeding period, usually the high point occurring in fall (Terman 1968:420). This approach can provide comparative numbers, relatively undisturbed age structure, and indicate breeding status. Adding assessment lines can yield density estimates if required. Sampling timing should recognize seasonal breeding patterns associated with latitude and moisture — the "northern" and "southern" breeding cycles. Trapping duration is a compromise between long enough for maximum trap exposure for residents, but short enough to avoid stress on animals. Five or 6 days is common; less time may produce small samples. Extending a trapping period is not advisable because repeated handling causes stress and weight loss, particularly during inclement weather. Live-trapping stress can be reduced by minimizing the time animals are confined. Most trapping is conducted once or twice a day. Disadvantages are that the species, particularly diurnal ones, will be confined for lengthier periods than their normal activity, depending if they enter a trap at the end of their daily cycle; e.g., a chipmunk caught at sundown. Voles are active day and night but they have poor survival from long confinement. I suggest a seldom-used technique that can enhance survival and increase trap availability and effort without increasing trap quantities or sampling duration. It employs two trap checks made during darkness, one prior to midnight and the second ending in the hour of first reading light. Using this approach in aspen habitat, I caught 97% of live-trapped and 100% of kill-trapped deer mice during darkness hours. About 90% of the chipmunks were caught between 0900 and dusk (Halvorson, unpublished)[3]. Area size will determine index line distribution and configurations. Paired lines, 100 m apart with a 100-m end buffer zone and using 20 stations at 15 m spacing, would occupy about 13 ha (33 a) or a rectangle 282 m by 470 m (311 by 516 yd) in forest. Index lines in riparian habitat might be spaced end to end with only a 50 m lateral buffer and still represent the zone. But a 3 ha (7.4 a) meadow would barely contain two lines of 10 stations each without intruding on edges. One solution is to use shorter, circular lines

[3] Halvorson, C.H., Ft. Collins, Colorado. Manuscript on file at Denver Wildl. Res. Ctr. Field Station, U.S. Fish and Wildlife Serv.

with the possibility of reduced sample sizes. Another is to describe and sample the area as a mosaic, but this technique may cloud data interpretation. Although sampling in uniform habitat is desirable and statistically necessary for studies that test treatment effects, the baseline inventory purpose of RNA monitoring could be less structured if the following are observed: 1) consistent methods are applied on permanently marked plots in a standard time frame; 2) sites are described in conventional terms used for habitats. With these guidelines unconventional or nonstandard sampling patterns could be used when needed because the primary comparison would be within sampling units between years.

A second but unconventional configuration and dispersion of sampling units is suitable if the above standards of consistency and site description are used. The method apparently was developed by Patric (1958) and applied by Peterle and Giles (1964), but has rarely been used. Some principles of the method were independently suggested and used by Hansson (1967). "Rosette" clusters of eight live traps were distributed in an approximate stratified grid. The clusters were spaced 61 m (200 ft) apart and traps evenly placed in a circle within 1.5 m (5 ft) of a point (station). The wide space between stations was intended to reduce trap station interaction. Patric (1958:163) referred to a "critical trap interval.... the minimum spacing at which traps cease to compete for a small mammal with a given cruising radius." The commonly used 10-15 m station spacing is well within most rodents' usual travel and traps do compete. Hansson (1967) recommended index lines of widely spaced (25-50 m), dense (5-10 traps) clusters, but additionally used a large radius (5 m) about each point to set traps within, and a single 24-hour setting as a precaution against change in the population. The intent of these wide spacing methods is to extract noninteracting samples from an area. Interaction may occur at each trapping point but this distributed-spot method has more merit for pattern flexibility than long lines and is worth testing. If kill-traps were used in distributed spots of 8-10 traps, and stations moved within the site condition each season and year, the area of effect would theoretically be diffused and disturb populations less than repetitive trapping at the same location along permanent lines. The concept of dense trap clusters widely spaced, using pre-baiting, and index trapping for a brief period, merits consideration for natural area use.

Birds

Songbirds should be an ideal subject to monitor. They are evident by sight and sound and their presence is predictable — daily and seasonally — during migration and breeding periods. In contrast to inventorying small mammal populations, only binoculars and data sheets are necessary equipment. However, the information obtained from bird monitoring techniques is severely limited and you should not expect more than species identification and presence. You cannot tabulate physical characteristics to associate with changes in an abundance index. If small mammals do not enter your data field (trap), you are either absolved or productive because they control your access to them and they register themselves as too scarce to be counted, if not caught. With bird counting a good portion of some eight biases associated with measurement error (Dawson 1981b) may be with the observer (McDonald 1981) and you bear the onus of weak data. For this reason observer error should be controlled and other variation minimized by standardizing the conditions of season, day, and time when monitoring. Individual bird and species behavior and the effects of habitat on detectability cannot be controlled, but might be estimated (Ralph and Scott 1981:252-261). Ralph and Scott (1981) is the primary reference for a bird monitoring program. An overview of counting methods is summarized by Mannon and Meslow (1981) for songbirds, and Martinka and Swenson (1981) for game birds. I will only mention a few general considerations.

There is a more realistic opportunity to approach an absolute census of birds than for rodents. Most song birds are conspicuous and exhibit territorial behavior during the breeding season. A spot mapping technique (Audubon Field Notes 1970) uses repeated visits to a plot where each detected bird is marked on a map, and the cluster pattern of individual locations gives territorial boundary limits translatable to density. But this method is very costly in time and not error-free (Dawson 1981c).

It was reassuring to read Emlen (1981): "...that indices of relative abundance are adequate and preferable to density estimates for most if not all projects concerned with population responses..." Thus, ornithologists and mammalogists seem in harmony that indices of relative abundance are entirely suitable for long-term monitoring.

A bird abundance index is measured in number of birds detected (seen or heard) per unit effort under standard conditions of daily time, season, and weather. One approach is to count along a walking transect and present abundance as the number of birds detected per distance or time. Alternatively, a station count uses a series of fixed points when birds are counted for set time intervals and the expression is number of detections per station (Mannan and Meslow 1981). Variations of each index method exist and Ralph and Scott (1981) should be consulted. Areas larger than 10 ha (25 a) are desirable. The starting date in spring can vary and should be cued to weather and plant phenological indicators such as bud burst or early flower bloom. Phenological records of plants are available for the Northern Rockies (Mueggler, 1972; Schmidt and Lotan 1980). A cold wet spring can delay migration and nesting for weeks, and also the availability of insects that most birds use heavily during nesting.

Dawson (1981b) suggests that monitoring design include a large number of replicates visited in standard fashion yearly. Trade-offs exist between the number of replicates per area and number of areas to be surveyed in a limited seasonal and daily time-frame. Rare species should first be located and then trends recorded at those sites rather than attempt a random sample. If habitats are not too diverse, indices can be compared if detectability biases are recognized. Topography and vegetation density and structure are but some habitat variables affecting detectability (Dawson 1981a). Raptor numbers and nesting success can be monitored by direct observation since nest sites are often reused (Call 1978; Fuller and Mosher 1981). Special precautions against disturbance must be observed. Bird counting from spring through winter is less definitive because territories break up, young are transitory, and birds shift their feeding areas frequently.

ACCESSORY INFORMATION FOR VERTEBRATE MONITORING

Information on the conditions and circumstances under which populations are sampled is an invaluable record. The conditions at sampling time plus characteristics of the location are basic information. Simple weather facts pertinent to animals are inexpensively provided with a maximum-minimum thermometer, rain gauge, sling psychrometer, a wind chart or gauge, and estimates of cloud cover and moon phase. Sophisticated but expensive devices can give continuous records. Environmental influences can provide clues to population performance, as in the case where rainfall was correlated with estrogenic potency of three African grasses, an effect similar to that achieved in experimental studies with wheat and voles in the U.S. (Delaney 1974:34). Bird counting is most suitable with little wind, no or faint precipitation, and nonextreme temperature (Robbins 1981). Nocturnal rodent activity shows positive response to rainy, cloudy, moonless, warm humid nights, with temporarily reduced movement on very cold nights (Vickery and Bider 1981). Habitat features that have been related to bird and mammal presence include ground cover, plant canopy and density (also logs and stumps), and plant structural features (layering, crown volume). Duff and litter depth and soil permeability are easily measured (Kitchings and Levy 1981; Brown and others 1982). Seeds are a basic energy source for many birds and rodents, but crops are seldom measured. Seed crop production and periodicity, especially trees, are readily measured with collectors and should be included. The seed production and periodicity of shrubs and other plants should be measured. Unfortunately, there is no national system to monitor tree seed crops in forestry. A final basic need is to collect and deposit specimens of the animals studied (Finley 1980). When verified and deposited in a museum they become archival information and a critical part of the monitoring record. Such collections can be made during a pilot study.

A pilot study is a preliminary trial and evaluation of a proposed operation. Project-type resource monitoring efforts often seem unable to afford trial runs. While skillful indoor planning and relying on familiar or convenient techniques may allow full-scale implementation right from the planning stage, a break-in time might be far more cost-effective. Dean (1984) in reviewing Adolph Murie's naturalistic grizzly bear study, reflected: "...it may be worth reminding ourselves that too many do not take, or are not given, time to learn their subject before jumping into research with borrowed hypotheses, complex tools, and quantitative fragmentation. First should come enough personal experience to develop a feel for what is there, perhaps the basis for one's own hypothesis, and the knowledge as to which end of the beast to which to attach the tools." Similarly, after 12 years' experience in environmental assessments, applying state-of-art computer simulations with process and baseline studies, Hilborn and Walters (1981) acknowledge that their "good" environmental predictions more commonly arose from "some qualitative understanding" about a system's behavior and construction than they did from more expensive and sophisticated approaches. They report that the key to understanding in a spruce budworm program, where birds, trees, and the insect interacted, was qualitative knowledge about those constituents and the ecosystem where they occurred. The keys were experience and thought, things machines do not develop. A pilot study period of up to 2 years can provide a species inventory, select phenological markers, develop cost estimates and time schedules, and suggest procedures to discard before they become locked into the program.

If many organisms and systems are monitored in a research natural area, problems with scheduling the data collection have to be considered. Some work can be interspersed with a principal effort, such as bird counts and collecting seed trap contents. Also, there would be little conflict between bird and small mammal monitoring if birds were counted in spring and winter with small mammal data collected right after spring bird counts and again in fall. Habitat descriptions might fit into the summer flowering period. Since the index procedures used for vertebrate monitoring are limited to identifying patterns and presence, accessory information augments our knowledge of natural process.

INFORMATION NEEDS

Perhaps when we can construct a functioning food web in a pond or on a forest plot, we will truly know wildlife needs. We do not have that sophistication yet. The search for ecosystem understanding proceeds in sequential steps, slightly modified from Wellner (1972): 1) classification; 2) identification of components; 3) description of patterns; 4) determination of process and production; 5) delineation of factors influencing production;

6) description of pattern, productivities, and function under alternative use. Baseline monitoring in and outside of a RNA would include steps 1 thru 3. Intensive research inside or outside of a RNA would add steps 4 and 5. Step 6, would be done outside a research national area to keep intact the concept of a RNA, but it could serve as an experimental control.

I have concern for those who say we have all the information we need to manage our resources. That belief is sure to result in a high percentage of Type II errors, accepting a hypothesis when you should reject it. While it is necessary to plan resource management on available and predicted information, it is detrimental to safe husbandry and learning the truth if we direct the main part of our efforts to applying current wisdom to drive our models, at the expense of improving our knowledge base. Probably few really believe our information base is adequate and reliable, but some computerized wildlife data bases may give that illusion, and this is as harmful as a mistaken belief. What we really known about wildlife, especially nongame species relative to the prior six steps, is that we have a working knowledge for step 1 and 2, scattered reference material for step 3, uncertainty and little proof for 4 and 5, and essentially nothing but ax handle judgement for predicting impact (6). Yet we currently try to manage resources and make predictions about animals from information anchored in step 2 (knowing the parts and where they live), and bravely leaping the chasm of ignorance containing 3, 4, and 5 (how these parts operate together) to prophesy what happens when the system is disrupted (step 6). To paraphrase Dobzhansky (1966), an ecosystem is not a mixture of plants and animals stirred together, it is an integrated system that arose as a result of two billion years of organic evolution. Woodwell (1977) explains that natural systems have solved their problems in diverse ways; solar power, continuous yield, recirculated water, renewable nutrient fluxes, and stable (relative to time) populations.

Research natural areas, using baseline monitoring, can meet a primary information need on vertebrates, that of long-term (over 10 years) population patterns. The value of monitoring would be magnified if comparative data are collected along some gradient of moisture, altitude, or succession. A second need is to complete our habitat-wildlife association catalogues to determine what exists in undisturbed and unique situations. Third is a need for a process to integrate and display the bird, mammal, and herptile patterns that come from monitoring. A suitable display format might resemble Fig. 4, which depicts patterns for three small mammals, set against plant ground cover changes over a 100-year forest cutting rotation. This is a parts catalog that managers could use, based on long-term experience. Our present wildlife data bank programs represent a first step of mixed quality; they do not advise the consequences of management actions because we are uncertain of the relationships between impacts and the true needs of most animals.

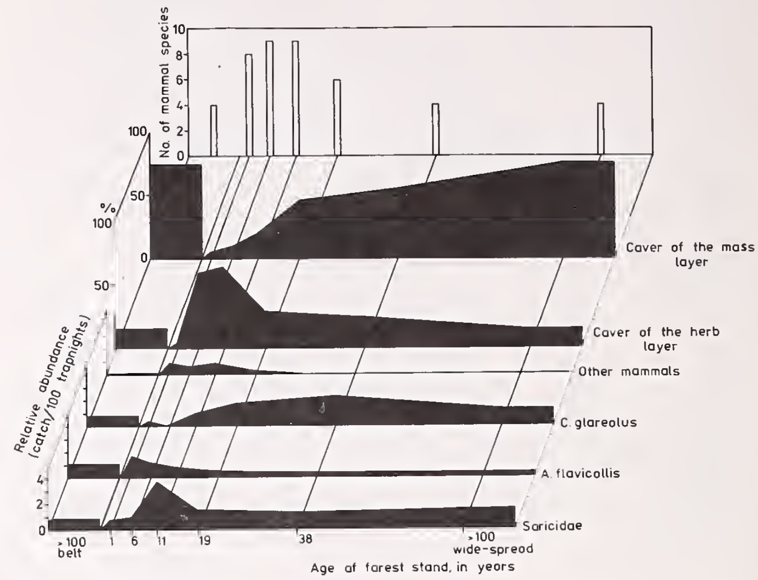

Figure 4.--A format that integrates small mammal abundance and vegetation cover with coniferous stands of different ages (reprinted by permission from Wolk and Wolk 1982).

A last and pragmatic institutional need is some provision in our career ladders and program planning to conduct long-term monitoring. A not original observation is that career payoffs are mostly in the form of specialty products that meet the current need or capture the fads. Exercise physiologists tell us that muscle fibers of sprinters are 70-80 percent "fast-twitch" muscles and those of marathoners are 70-80 percent "slow twitch." Fast-twitchers can leap chasms with a powerful energy burst, exhaust that and change directions. The slow-twitchers have to walk down one side, across, and up the other and continue the path. Each type can do a job but career awards largely go to the sprinters. We either need to give recognition to the reciprocal part of each worker or support long-distance training. Iker (1984) details the substance and style of some long-term research scientists.

CONCLUSIONS

What can we expect to get from baseline monitoring in research natural areas? We would assemble a list of species in association with each other and their habitats. Long-term patterns of population variability would be developed, along with an appreciation for "normal" variability, which is not as definable with short-term study. There would be parameters to refine models and suggest paths and relationships to explore and test. What we should not expect are absolute densities, a detailed picture of animal demographics, proof of animal habitat needs and dependencies, (except inferentially), and responses by communities to disturbance, unless a natural experiment occurred.

Certain guidelines that can facilitate the conduct and success of monitoring should be reemphasized. 1) A long term commitment to funds and personnel must be upheld. This should be part of the planning design. 2) Techniques should strive for simplicity and economy. Indices of relative abundance meet these criteria. 3) Standardized methods, applied consistently, are necessary for biological and statistical validity. Methods should match objectives. 4) Data should be suited for computer processing but not at the expense of access or visibility by less technical means. A machine should not drive out thought and experience. 5) There should be biological sense in design and data collection. 6) Accessory knowledge about the sampling environment is needed to frame the patterns as they unfold. 7) Finally, a pilot study should be allowed to explore and test so that thoughtful choices can be structured to achieve goals. Research natural areas have a unique role to play simply by existing as natural controls and serving to convey patterns, if we are serious about listening.

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THE ECOLOGICAL PROFILE AS A MONITORING TOOL FOR LAKES IN YELLOWSTONE NATIONAL PARK

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ABSTRACT: Within Yellowstone National Park, over 150 lakes constitute 5 percent of the 899 000 ha. Since 1964, 112 lakes have been surveyed utilizing a holistic system consisting of basic physical, chemical, and biological parameters. The result, the Ecological Profile (EP), has allowed identification of unique features of each lake while providing data necessary for monitoring future changes and development of a general classification system. In conjunction with the Volunteer Angler Report, the EP has provided an economical means of evaluating human impacts of Park lakes.

INTRODUCTION

With a surface area of approximately 899 000 ha, Yellowstone National Park is one of the largest natural area preserves in the United States. Over 5 percent of the Park is covered by water, and lakes, lying at elevations between 1 680 m and 2 960 m, constitute approximately 43 000 ha. Four deep oligotrophic lakes, Yellowstone Lake, Shoshone Lake, Lewis Lake, and Heart Lake, account for 94 percent of the total lake surface area.

Although some information concerning the larger lakes was collected during the first half of the century, little was known about 130 smaller lakes scattered throughout the Park. In 1963, the National Park Service requested that the U.S. Fish and Wildlife Service fishery assistance office begin an inventory of lacustrine systems. Basic elements of the program included description of lake characteristics and acquisition of baseline data necessary for comparison through time.

Time and monetary constraints limited the program; consequently, a procedure that provided the information necessary for management purposes also had to be cost-effective. Initial efforts utilized standard lake survey techniques (Lagler 1956), and these studies emphasized the fishery potential of the various lacustrine waters. Methods changed somewhat between 1967 and 1972 with increasing effort on chemical parameters. Although fish sampling was originally conducted by experimental gillnet and hook and line methods, reliance on gillnetting alone increased precision and reduced the time spent on each lake, thereby reducing cost.

After reviewing procedures in 1973, it appeared that plankton, macroinvertebrate, and macrophyte sampling should receive greater emphasis. Beginning in 1974, commercial analysis of water samples substantially increased accuracy and the number of chemical parameters that were routinely evaluated while greatly reducing the time for field collection and analysis. This reduction more than compensated for extended time necessary for biological sampling. It also became apparent that more rigorous examination and synthesis of these data would provide greater insight into lacustrine dynamics.

The sampling and analytical system that ultimately evolved, the Ecological Profile (EP), is a holistic approach for examination of lakes in Yellowstone National Park. Through a system of qualitative and quantitative measurements, the EP focuses on the interaction between the watershed geology and vegetative cover, and the physical, chemical, and biological characteristics within each lake.

METHODS

A survey team of two individuals generally spends 2 days at each lake. A map of each lake, drawn to scale from 1:15840 aerial photos prior to field work, provides a basis for bathymetric studies and mapping of the surrounding basin.

Depth is measured along transects established at the time of the survey; the deepest spot in the lake is then utilized for pelagic sampling. Secchi disc visibility and temperature profile are measured at this station. Observations of lake color, turbidity, and wind exposure are recorded. Substrate type and variability are sampled at numerous points throughout the lake with an Ekman dredge.

Exploration of the immediate watershed provides additional physical information concerning riparian vegetation, erosion, angler trails, litter, and human modifications. Flow measurements are taken for all inlets and outlets, and descriptive data concerning permanency, gradient, pool-riffle ratio, substrate, productivity, and barriers to fish movement are noted. General characteristics of the watershed (topography, soil, cover) are also recorded.

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During data analysis mean depth is estimated using the bathymetric map constructed from field measurements. Lake surface and drainage area are calculated from 15 minute series, USGS 1:62,500 topographic maps utilizing a dot-grid sheet. Together these data yield an estimate of total volume, and in conjunction with inlet and outlet flow, a flushing or exchange rate can be calculated. Lake maps also provide data for computing shoreline development. Geological description of the watershed is generated from USGS geological and surface geology maps of Yellowstone National Park.

A single midwater sample is collected from each lake at a depth of 2 m. A certified commercial laboratory furnishes chemical analyses for 38 different parameters in each sample including total dissolved solids (TDS), alkalinity, hardness, nitrogen, phosphorus, and major and minor ions. Measurements of conductivity, pH, and dissolved oxygen are taken in the field.

Numerous samples are taken for littoral and benthic macroinvertebrates, but plankton collection is limited to a single 9.1 m oblique tow. Preserved samples are returned to the laboratory for identification and quantification. The various locations of aquatic macrophytes are mapped, and samples are pressed for later identification.

One smallmesh (10-19 mm bar mesh) and two largemesh (19-51 mm bar mesh) experimental gillnets are generally set overnight. Measurements of length and weight are recorded for captured fish, and scales are collected for age and growth determinations. Cursory observations of stomach contents are also noted.

Ecological Profile (EP)

The EP is a synthesis of data that describes the major components of lake systems. Source materials that aid in interpretation include Hem (1970), Hutchinson (1967, 1975a, 1975b) Macan (1974), Moss (1980), and Wetzel (1975). The data base produced from all prior lake surveys provides additional information that enhances conceptualization. Understanding the interaction of chemical and physical parameters and the extent of their reflection in the biological community is essential to the EP. The presence or absence of various key organisms or types of organisms is used to indicate general sets of conditions. In conjunction with the identification of unique components of the system, these data help to evaluate changes through time. Assessment of the effects of human activities is utilized to predict the impact of future activities on various lake systems.

RESULTS AND DISCUSSION

A total of 112 Park lakes have been surveyed in the past 20 years. During this period, eight lakes have been visited twice, three lakes have received three visits, and one lake has been surveyed five times. The EP has enhanced the basic understanding of these waters, unique features have been identified and catalogued, and results have provided baseline data.

Evaluation of the structure and condition of the fishery is an important facet of the system; however, the presence or absence of fish is by no means an endpoint. In a designated natural area, such as Yellowstone Park, those waters that are historically fishless, or have reverted to a fishless condition, have a value equal to those that support a fish population. Fishless lakes, which commonly sustain distinctive lifeforms, offer a significant opportunity to appreciate rare communities as well as to investigate the effects of fish on community structure. Although there may be many hundreds of lakes in this country that can sustain fish life but lack reproductive habitat necessary to support a viable population, many of these currently support fisheries through frequent stocking. Because fish have not been planted to maintain wild trout fisheries in Yellowstone Park since 1954, the Park may encompass a significant proportion of this type of fishless lake in the country. The various forms of amphibians, macroinvertebrates, and plankton found only in fishless waters form a series of communities that are poorly documented.

The EP also provides excellent monitoring capabilities for lakes that do support fisheries. An independent, although integral system, the Volunteer Angler Report (VAR), provides annual statistics concerning angler use, harvest, and success for approximately 40 lakes in the Park. By utilizing the sizes of captured fish reported by the VAR with size and age structure data from experimental gillnets, the status of fish populations is assessed annually. This system allowed detection of severe declines of cutthroat trout in several Park lakes, and currently, monitoring studies are being conducted on four lakes to evaluate the effects of recent changes in angling regulations. Several populations of introduced species, including one that was later removed, have been identified during the EP evaluation.

By utilizing the holistic properties of the EP, all facets of a lake ecosystem can be compared to previous surveys in order to investigate possible causes for any observed trends. Preserved specimens of flora and fauna are indispensable for the detection of future change. Chemical data collected in conjunction with this program have also been utilized in an independent study concerning the susceptibility of waters in the Rocky Mountain area to acid precipitation.

In addition to baseline data acquisition and monitoring capabilities, the EP has been utilized as a foundation for a general classification system. Preliminary analysis of water chemical data indicated eight basic lake types within Yellowstone Park. Although continued analysis is necessary, it appears that sodium bicarbonate, calcium bicarbonate, calcium sulfate, sodium sulfate, sodium chloride, calcium chloride, magnesium bicarbonate, and dilute waters are types that appear to have distinctive biological characteristics. The relationship between water type and geological substrate of the watershed has also demonstrated lithological influences on the water chemistry of Park lakes.

Additional analyses have investigated the use of productivity indices such as the Trophic State Index (Carlson 1977) and the Morphoedaphic Index (Ryder 1965; Ryder and others 1974). It appears that these indices may have potential for classification of Park lakes, especially for those that support a fishery; however, substantial time and effort will be needed in order to fully integrate such indices into a comprehensive system that may also be useful outside Yellowstone Park. Future attempts at classification will also incorporate other characteristics of the EP including macrophytes, plankton, and macroinvertebrates in conjunction with additional physical limitations.

The EP has proved to be a valuable management tool in numerous ways. By identifying distinctive or unique species or ecosystems, it has an important deterministic feature. The system integrates known lake ecosystems with annual angler data so that human exploitation can be efficiently monitored. Future changes can potentially be explained because of baseline data acquisition, especially if replicate surveys are completed and reference collections are maintained. The EP has formed the basis for a classification system that will enhance the understanding and management of Yellowstone Park lacustrine systems and perhaps in the future, other systems in the Northern Rocky Mountains as well. Finally, as agency budgets continue to decline, the current cost of less than $1,000 per lake seems to be a reasonable cost to protect and preserve one of the most important natural area ecosystems remaining in the continental United States.

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INTEGRATED MONITORING IN MIXED FOREST BIOSPHERE RESERVES

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ABSTRACT: Sampling took place at Glacier National Park at two sites, an exposed and a remote site, in 1981 and 1982. Samples were analyzed for trace elements, sulfates, and nitrates. Media sampled included air, water, soil, vegetation, and forest litter. In general, atmospheric values measured reflect current literature estimates of background levels for these compounds. Moss samples and forest litter appeared to be enriched relative to crustal sources for such elements as lead, copper, and zinc. Two sites were instrumented for surface hydrology measurements. These efforts proved to be successful and demonstrated the feasibility of monitoring hydrologic limitations on very remote sites.

INTRODUCTION

This paper describes pollution monitoring that took place in Glacier National Park, Montana, a U.S. Biosphere Reserve. The biosphere reserve program is a component of the Man and Biosphere Program coordinated by the United Nations Educational, Scientific, and Cultural Organization (UNESCO). The biosphere reserve program is also coordinated with the United Nations Environment Program's Global Environmental Monitoring System (UNEP/GEMS). UNEP/GEMS has agreed to fund the establishment of a three-station pilot network for background monitoring. One of these sites will likely be in the United States, probably at Olympic National Park. The work discussed here has contributed to the development of the techniques and data bases necessary to conduct monitoring at global background stations.

METHODS

Some of the methods used in this study have been previously described (Wiersma and others 1979a; Wiersma and others 1979b; Wiersma and Brown 1981; and Brown 1981). Air sampling techniques were modified from previous studies and are described in detail by Davidson and others (1983).

The methodology for acid extraction of elements from soils is described below. After collecting the soils, they were transferred to No. 8 brown paper bags and dried for 24 hours at 40°C in a drying oven. After cooling to room temperature, the samples were sifted through a No. 20 (850 micrometer opening) standard testing sieve. Ten grams of the homogenized soil sample were then placed in 500-ml round-bottom flasks, to which 36 ml of concentrated nitric acid was added. Once foaming subsided, the mixture was refluxed for 18-20 hours. After digestion, the contents of the flasks were cooled, made up to 100 ml with the addition of deionized water, and filtered. Samples were then submitted for analyses. All analyses were performed in triplicate using an inductively coupled plasma emission spectrometer (ICP).

Plant and forest litter samples must be prepared prior to analysis by optical emission spectrometry (Alexander and McAnulty 1981). Preparation consisted of transferring samples to No. 8 brown paper bags and drying for 24 hours to 40°C in a drying oven. After cooling, the material was homogenized by use of a Spex Mizer/Mill. Plastic gloves were worn when transferring material to crushing vials, etc., to prevent contamination of samples.

SITE SELECTION

The objectives in selection of sites in Glacier National Park were to:

1. Determine the background levels for certain types of pollutants in Glacier National Park

2. Determine if there was a difference between a site close to human activity and a site that is more remote

To achieve these objectives, two sites were selected in the park. Site A, Martha's Basin, is shown in figure 1. Access to this site was only by trail. The site was 29 km from the trail head. No mechanized devices were used on the site, nor were any aircraft used to bring in supplies and equipment. Site B, Toad Valley, is also shown in figure 1. This was considered an exposed site and is located 3 km from Logan Pass visitor's center and Going-to-the-Sun Road. Both of these sites were chosen because they have similar aspects, vegetation types, drainage patterns, and altitude. A third site at Polebridge (fig. 1) was sampled for air concentrations only. This site was relatively close to a road.

At sites A and B, atmospheric concentrations were sampled for trace elements, sulfates, and nitrates. Dry deposition samples were collected. Stream chemistry samples were collected for trace elements, pH, conductivity, and total alkalinity. Selected vegetation samples, forest litter, and

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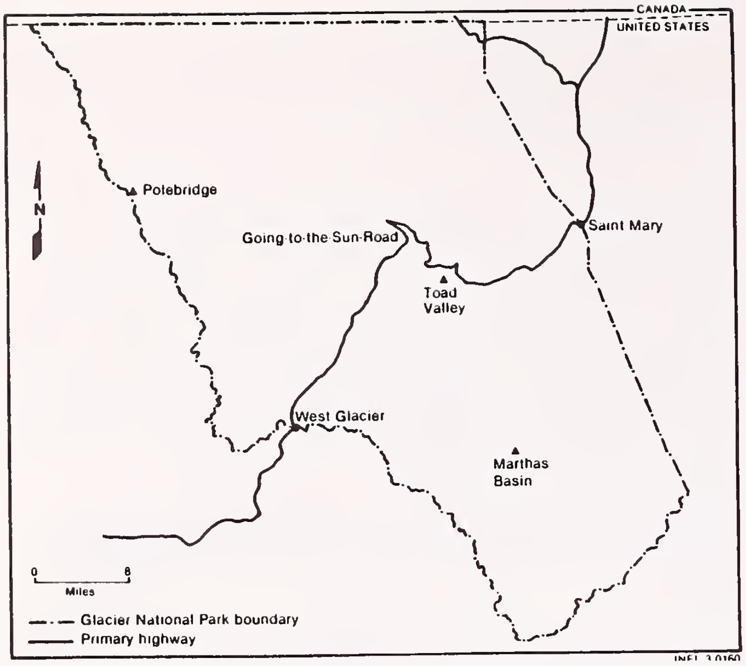

Figure 1.--Location of study sites in Glacier National Park, Site A - Martha's Basin (remote site); Site B - Toad Valley (exposed site)

soil samples were collected for trace element analysis. In addition, stilling wells and pigmy stream gauges were used to determine surface flow from each of these discrete watersheds. An automatic tipping bucket rain gauge was installed at site B to determine rainfall. This paper describes only the results for air, vegetation, litter, soil, and some of the results of the hydrology study.

Parallel sampling of vegetation was attempted in 1981 and 1982. However, Toad Valley could not be sampled in the fall of 1982 due to an early snow storm.

QUALITY ASSURANCE

An extensive quality assurance program was implemented. About 10 percent of all samples submitted were quality assurance samples. These samples were either known tomato leaf standards or replicated samples. For soil samples, a prepared standard solution was submitted along with the regular soil extracts. Quality assurance samples were submitted blind and at random to the analytical laboratories.

Table 1 is a summary of the quality assurance samples (NBS tomato leaf standard) submitted along with vegetation and litter samples. Approximately one sample and three replications went into each value in the table. Samples were analyzed by optical emission spectroscopy. In general, the results were acceptable. The criteria used were to accept the values presented if they were within ±25 percent of the NBS value or the upper and lower ranges of the NBS value. It should be pointed out that certified values for compounds such as aluminum, sodium, silica, etc., were not available. However, since the analytical procedure is a multielemental technique in which a single sample is analyzed for 26 elements at one time, one can probably draw the inference that if 14 of the 26 elements are good, then within reason the remaining elements have a certain degree of reliability.

Table 2 shows the quality assurance results for soil. Soil samples, as mentioned in the Methods section, were submitted as acid extracts. A standard solution with known values was submitted, along with our regular acid extract samples, acid blanks, and distilled water blank samples. All soil values reported have been corrected for these blank values. Based on the results, the soil values for barium, cobalt, silver, and strontium were rejected while the rest of the values were accepted. Because there may have been some problems with the quality control standard (the standard may have been kept too long), the acceptance criterion for trace elements in soil was broadened.

RESULTS - TRACE ELEMENTS

Table 3 shows the results for the air sampling for both Martha's Basin and Polebridge. The Toad Valley results are not reported because of the strong probability the samples were contaminated. For the most part, values for the Polebridge filters tended to be higher than those samples collected at Martha's Basin (remote site). This is true for both crustal elements and those that are suspected of having potential for enrichment.

Data for moss are shown in table 4. For the comparable data (Toad Valley vs. Martha's Basin for the summer of 1982), in the majority of cases for the elements listed, the values are higher at Toad Valley than they are in Martha's Basin. However, some values must be used with caution. For example, there appears to be a significantly larger amount of lead (333 µg/g vs. 124 µg/g) at Toad Valley than at Martha's Basin; but the quality assurance results for the same set of samples indicate unacceptably high lead values for the quality assurance samples from Toad Valley for moss.

In general, the results for moss between summer and fall 1982 appear to be very consistent. The exceptions are reduction by almost one-half for lead values and one-half for zinc values. Finally, Martha's Basin fall values from 1982 had higher lead, copper, iron, magnesium, and manganese levels than the fall values for 1981. A possible explanation for this is that Martha's Basin samples collected in 1981 were not actually in Martha's Basin. In 1982, the site was moved into Martha's Basin proper, a distance of about 3 air kilometers from the 1981 site.

Table 5 shows the results for other types of vegetation, primarily subalpine fir, *Abies lasiocarpa*, and woodrush, *Luzula hitchcockii*. In general, values for these forms of vegetation are lower than for moss for certain types of elements, for example, lead and copper.

Table 1.--Summary of quality assurance results from samples submitted with vegetation, moss, and litter collected in Glacier National Park (values in µg except where noted)

	Fall 1981					
	Martha's Basin			Toad Valley		
Element	Moss	Litter	Subalpine Fir	Litter	Subalpine Fir	Woodrush
B	34.6 ± 5	27.8 ± 6.9	33.6 ± 8.8	27.5 ± 5.7	28.6 ± 3.7	31.2 ± 6.6
Cd	2.8 ± 0.8	1.8 ± 0.1	3.6 ± 0.6	2.8 ± 0.8	2.4 ± 0.4	2.9 ± 1.8
Ca (%)	2.95 ± 0.3	3.53 ± 0.48	3.04 ± 0.24	2.88 ± 0.18	2.61 ± 0.24	2.97 ± 0.3
Cr	3.1 ± 0.1	3.6 ± 0.9	5.9 ± 0.4	4.3 ± 0.9	5.2 ± 0.7	4.9 ± 0.9
Co	0.8 ± 0.2	0.5 ± 0.1	0.6 ± 0.1	0.9 ± 0.2	0.8 ± 0.1	0.9 ± 0.2
Cu	11.0 ± 0.5	8.8 ± 1.2	11.0 ± 0.9	11.3 ± 0.5	11.9 ± 1.4	12.1 ± 1.3
Fe	674 ± 73	706 ± 98	656 ± 35	671 ± 12	715 ± 62	713 ± 57
Pb	7.0 ± 5.6	2.1 ± 3.8	6.1 ± 5.2	6.2 ± 6.1	-0.8 ± 1.9	1.9 ± 0.0
Mg	6800 ± 223	7200 ± 300	6660 ± 187	5700 ± 367	7420 ± 504	7230 ± 372
Mn	232 ± 28.7	228 ± 11	244 ± 18	245 ± 16	244 ± 25	235 ± 21
Sr	44.2 ± 2.5	48.5 ± 3.4	45.5 ± 3.2	43.2 ± 1.7	42.6 ± 2.7	45 ± 3.2
Zn	68.5 ± 7.0	83.2 ± 9.6	55.6 ± 0.9	73.2 ± 10.4	41.1 ± 8.2	50.3 ± 4.4
P	4370 ± 87	3920 ± 118	4620 ± 209	4070 ± 193	4030 ± 268	4070 ± 417
K (%)	4.13 ± 0.23	5.35 ± 0.69	4.78 ± 0.48	3.86 ± 0.22	4.37 ± 0.20	4.28 ± 0.10

	Summer 1982					
	Martha's Basin			Toad Valley		
Element	Moss	Litter	Subalpine Fir	Moss	Litter	Subalpine Fir
B	24.6 ± 1.3	27.8 ± 2.5	29.6 ± 4	26.0 ± 7	30.9 ± 1.6	28.6 ± 4
Cu	10.7 ± 0.2	10.8 ± .5	12.3 ± 1.8	10.6 ± .8	11.9 ± .9	10.1 ± .7
Fe	566 ± 96	524.9 ± 36	535 ± 90	400 ± 37	517 ± 46	394 ± 37
Pb	5.0 ± 4.0	ND	6.0 ± 5	15.8 ± 8	9.8 ± 8	18.8 ± 8.7
Mg	6698 ± 189	6303 ± 434	6541 ± 783	5447 ± 770	7074 ± 563	4834 ± 857
Mn	213 ± 8.8	273 ± 4	240 ± 10	214 ± 3	230 ± 45	212 ± 18
Sr	39.1 ± 3.1	36.9 ± 2.4	42.1 ± 5	39 ± 5.6	47.3 ± 4.7	38.4 ± 6.8
Zn	73.7 ± 5.4	18.8 ± 7.0	59.9 ± 19	49.2 ± 7.5	56.1 ± 7.6	66.2 ± 8.9

	Fall 1982			
	Martha's Basin			
Element	Moss	Litter	Subalpine Fir	Tomato Leaf Standard
B	26.8 ± .9	26.6 ± 1.6	24.1 ± .9	30.0
Ca (%)		2.9 ± .2	3.2 ± .3	3.00 ± 0.03
Cr		7.4 ± 5	5.1 ± .2	4.5 ± 0.5
Cu	13.9 ± .8	11.6 ± .7	14.1 ± .4	11.0 ± 1.0
Fe	589 ± 93	523 ± 33	521 ± 44	690 ± 25
Pb	6.9 ± 5	5.1 ± 2	3.0	6.3 ± 0.3
Mg	7282 ± 632	5704 ± 269	7546 ± 435	7000
Mn	236 ± 8	206 ± 3	252 ± 7.6	238 ± 7.0
Sr	48.5 ± 3	41.7 ± 3.5	45.4 ± 5.7	44.9 ± 0.3
Zn	46.3 ± 2.6	43 ± 2	58.3 ± 4.7	62 ± 6.0

Table 2.--Summary of quality assurance samples submitted with soil collected in Glacier National Park (µg/g)

Element	Martha's Basin - A Fall 1981	Toad Valley - B Fall 1981	Martha's Basin - A Fall 1982	Martha's Basin - A Summer 1982	Toad Valley Summer 1982	Toad QA Standard
Al	0.981	1.30	1.41	1.55	1.71	----
As	2.95	3.03	3.13	3.54	3.71	2.0
Ba	0.721	0.722	0.607	0.617	0.399	20.0
B	5.18	5.09	4.49	4.76	4.61	4.0
Cd	0.337	0.341	0.444	0.495	0.514	0.2
Ca	149	143	139	138	130	203
Cr	4.31	4.18	3.85	3.88	3.69	5.0
Co	1.62	1.82	4.64	6.24	6.93	0.3
Cu	1.67	1.67	1.53	1.58	1.59	2.0
Fe	1602	1537	1618	1594	1479	2000
Pb	1.86	1.77	2.28	2.31	3.63	2.0
Mg	166	158	134	134	128	201
Mn	46.7	45.2	39.3	39.5	37.9	50.0
Mo	0.277	0.353	0.411	0.532	0.615	----
Ni	8.41	8.25	7.62	7.85	7.72	10.0
Se	0.249	0.278	0	0	0	----
Ag	0.082	0.09	.162	0.204	0.173	2.0
Na	48.8	49.7	46.9	47.7	47.3	59.0
Sr	36.8	36.5	32.6	33.0	31.7	8.0
Sn	3.25	3.09	3.07	3.13	3.07	2.0
Ti	0.037	0.041	0.039	0.39	0.035	----
V	0.034	0.043	.074	0.92	0.105	----
Zn	8.24	7.88	6.78	6.85	6.62	10.0

Table 6 shows the results for trace elements in litter samples for 1981 and 1982 at both sites. In general, it appeared that in 1981 Martha's Basin had lower levels of trace elements than Toad Valley. This relationship did not appear again in the summer of 1982, and could be due to the site relocation in Martha's Basin. The 1982 summer values for the two sites appear to be similar. Sampling results from 1983, when available, should help clarify these levels.

Table 7 shows the results for soil analyses for both sites and for both years. Those elements that did not have good quality assurance have been eliminated. Basically, the two sites have similar trace element compositions.

Standard deviations have been calculated for all values. No statistics have been applied at this time. Therefore, final conclusions concerning real differences cannot be made. These analyses will be made in the final report that will include all the 1983 data.

RESULTS - HYDROLOGIC STUDY

Precipitation and stream discharge data were collected during the summers of 1981 and 1982. Also, attempts were made to instrument the groundwater systems; these efforts were terminated because the hand-powered drilling equipment used was incapable of penetrating overlying material. The hydrologic data were sought in order to quantify the water balance within the study areas. Table 8 summarizes the type of information obtained.

The two field areas instrumented during this study are very similar in character. However, there are some differences which include: (1) the bedrock geology--Toad Valley is in limestone and Martha's Basin is in argillite, (2) the drainage area above the stream stage recorder--Toad Valley is 1.6 km^2 and Martha's Basin is 11 km^2, and (3) Toad Valley exposure is ENE--Martha's Basin is E.

A tipping bucket, recording rain gauge was temporarily installed at the Toad Valley site during the 1982 field season. No precipitation data were collected for Martha's Basin. Stream-stage recorders were placed in both areas during each season.

Two activities are included in the stage/discharge data acquisition. The first involved continuous monitoring and recording of changes in stream stage at the study sites. The second activity required periodic gauging of stream velocity at a specific stage level. These two activities provided data necessary to determine stream discharge variations through time and to estimate the total volume of water passing the recorder station as surface flow.

DISCUSSION - HYDROLOGIC STUDY

Stage hydrographs from Toad Valley show some response to local, concurrent rainfall events.

Table 3.--Preliminary airborne concentrations from Glacier National Park-1981 (ng/m^3 STP except where noted)

	Martha's Basin	Polebridge
CRUSTAL ELEMENTS		
Al	82	240
Ba	8.2	13
Ca	240	320
Fe	120	130
Mg	43	240
Mn	28	39
Na	650	150
ENRICHED ELEMENTS		
Ag	<0.16	.085
As	1.6	2.5
Cd	0.98	0.45
Cu	----	<6.9
Pb	4.6	4.6
Zn	----	9.0
Sulfate	0.73 $\mu g/m^3$ 1.48 $\mu g/m^3$	
Nitrate	>1.36 $\mu g/m^3$ 0.71 $\mu g/m^3$	

This relationship is illustrated by comparison of 1982 precipitation and stream flow records for August 30 and 31, and September 4 and 5 (figs. 2 and 3). Additional features of the Toad Valley hydrographs that may imply response to local rainfall include the sharp rise and fall of the 1981 record (fig. 4) and the steep drop in water level following the August 15, 1982, precipitation event (fig. 3). Long-lasting periods of high flow do not appear to be an immediate response to local precipitation events. These high flows may result from antecedent snowmelt or precipitation conditions, or unrecorded precipitation events

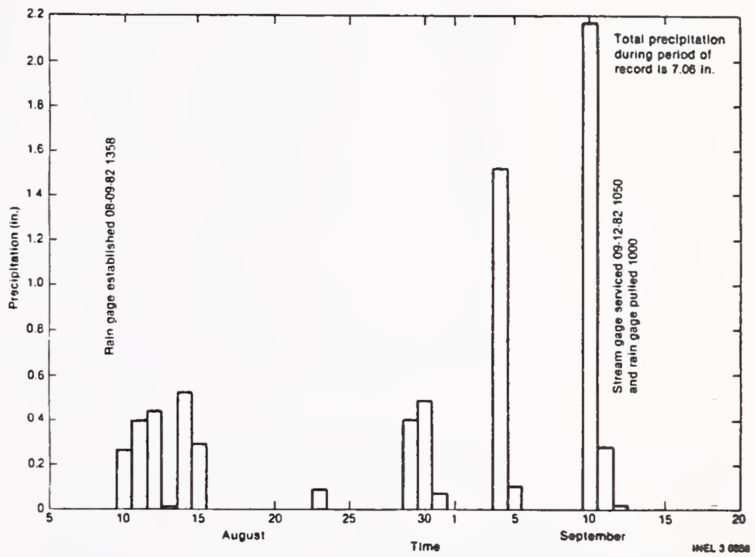

Figure 2.--Daily precipitation "Toad Valley" Glacier National Park, August 9 to September 13, 1982

Table 4.--Average concentrations of selected elements in moss from Glacier National Park (values on a dry weight basis - in µg/g except where noted)

Elements	Martha's Basin - A Fall 1981	Martha's Basin Fall 1982	Toad Valley Summer 1982	Martha's Basin Summer 1982
Al	1817	1840	2377	1915
Ba	236	229.5	166.6	213.4
B	6.07	11.4	17.4	12.5
Cd	0.825	ND	ND	ND
Ca	8852	7078	3159	5559
Cu	7.31	32.7	35.8	33.5
Fe	1093	4245	5187	4238
Pb	26.7	61.7	332.8	124.4
Mg	2196	4203	5129.5	4521.3
Mn	537	1186	944.4	1572
Ti	192	614	1025	772.6
V	3.7	13.0	36.6	20.3
Zn	67.5	23.5	29.4	47.0
Na	510	4096	8364	5084
Sr	86.2	43.3	29.22	37.9

Table 5.--Average concentrations of selected trace elements in vegetation collected from Glacier National Park (values in µg/g except where noted)

Element	Martha's Basin - A Fall 1981	Toad Valley - B Fall 1981		Toad Valley Summer 1982	Martha's Basin Summer 1982	Martha's Basin Fall 1982
	Abies lasiocarpa	Abies lasiocarpa	Luzula hitchcockii	Abies lasiocarpa	Abies lasiocarps	Abies lasiocarpa
Al	472	401	975	255.9	236.4	176.0
Ba	107	76.3	69.5	81.9	93.5	81.8
B	20.3	14.0	8.9	14.8	19.4	16.0
Cd	6.6	6.4	2.9	ND	ND	ND
Ca	1328	6262	4702	4770	4564	3959
Cu	2.57	1.99	2.56	4.6	5.3	6.2
Fe	182	140	728	112.8	87.5	70.1
Pb	5.69	30.4	15.68	4.1	4.6	4.55
Mg	1456	1253	1642	652.7	1062.4	966.0
Mn	839	434	515	529.2	560.4	366.1
Na	231	1207	281			
Sr	55.7	7.3	10.8	5.11	5.9	4.74
Ti	8.0	3.26	106	9.97	8.6	4.83
V	1.2	1.7	2.7	2.8	2.5	
Zn	40.1	45.0	209	40.2	47.2	47.3

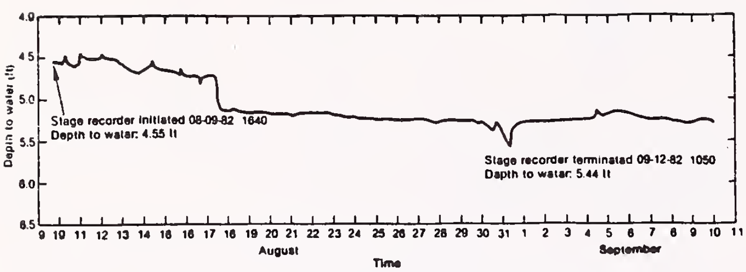

Figure 3.--Stream stage at "Toad Valley" recorder, Glacier National Park, August 9 to September 10, 1982

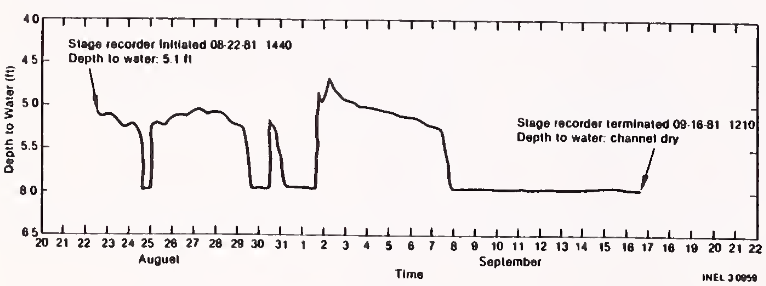

Figure 4.--Stream stage at "Toad Valley" recorder, Glacier National Park, August 22 to September 16, 1981

(1981 record). The long duration events may reflect temporary storage of water in surface depressions or in soils.

The 1982 hydrograph from Martha's Basin (fig. 5) exhibited an entirely different character from those obtained in Toad Valley. The slow, steady decline in stage shown by the Martha's Basin hydrograph seemed little influenced by concurrent rainfall, probably because of the large drainage area and the lakes present in the basin. Another

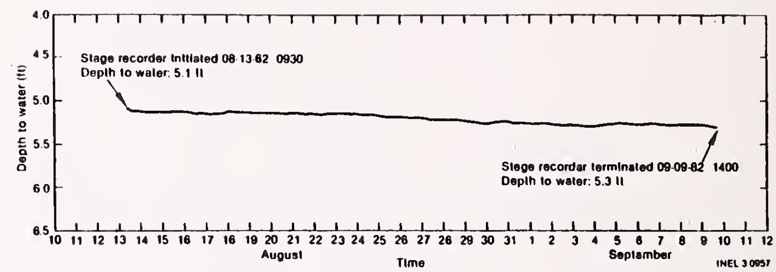

Figure 5.--Stream stage at Martha's Basin recorder on Coal Creek, Glacier National Park, August 13 to September 9, 1982

factor that may contribute to the hydrograph differences was the geology at each site. Toad Valley's fractured limestone probably allowed extensive underflow; Martha's Basin argillite (rock derived from clay or silt) allowed little or no underflow.

An initial estimate of the importance of various factors of the water balance equation can be obtained by comparing the volume of water entering the drainage area to that discharged. Concurrent precipitation and discharge data exist only for Toad Valley during the period August 9 through September 9, 1982. During this period, 11.7 cm of rain was recorded at the gauge. Under the assumption of uniform distribution of rain throughout the drainage area above the stage recorder, this rainfall was equivalent to 1.8×10^5 m^3. Thus, surface drainage accounted for 94 percent of the water entering the drainage area. This implied that very little water was stored in the drainage area and that the importance of other parameters in the water balance (i.e., evaporation, transpiration, infiltration) was small. These observations must be tempered by recognizing that this exercise was based on only 1 month of data and likely did not represent

Table 6.--Average concentration of selected elements in litter from Glacier National Park (values on a dry weight basis in $\mu g/g$ except where noted)

Element	Martha's Basin - A Fall 1981	Toad Valley - B Fall 1981	Martha's Basin - A Summer 1982	Toad Valley Summer 1982	Martha's Basin Fall 1982
Al	3158	5267	1537.0	1949.9	1475
Ba	330.2	253.1	190.5	167.3	182.7
B	10.22	19.29	10.84	16.6	11.6
Cd	6.11	5.58	ND	ND	ND
Ca	11456	6182	5667	6217	6994
Cu	21.83	56.32	20.36	27.6	24.5
Fe	2449	4615	3102.2	4030.6	3288
Pb	156.9	275.6	52.7	54.4	37.2
Mg	2088	7246	1778.1	4011	2495.3
Mn	1572	738	1795	1146	1324.5
Na	1754	3541	1308	2953	1854
Sr	96.08	36.3	30.0	25.2	28.6
Ti	460.7	1102	411	691	414.8
V	6.44	11.13	11.6	21.8	11.9
Zn	95.97	81.86	28.3	41.8	32.1

Table 7.--Average concentration of selected elements in soil from Glacier National Park Biosphere Reserve (values on a dry weight basis - $\mu g/g$)

Element	Martha's Basin - A Fall 1981	Toad Valley -B Fall 1981	Martha's Basin - A Summer 1982	Toad Valley - B Summer 1982	Martha's Basin - A Fall 1982
Al	8829	18390	13080	14249	12935
B	4.17	8.92	21.07	18.29	18.4
Cd	0.884	----	1.57	2.16	1.25
Ca	391	2249	1319	1331	1155
Cr	5.88	10.21	8.35	8.53	8.28
Cu	9.61	10.26	5.77	6.86	5.94
Fe	9902	16700	8592	11068	8951
Pb	9.08	25.7	8.69	9.0	7.83
Mg	1781.7	6418	6550	4334	6853
Mn	402	841	654.8	51.47	447
Mo	0.96	----	1.14	2.07	0.15
Na	106	66.9	109.4	136.96	90.92
Ti	260	509	186.3	291.05	172
V	16.4	30.0	15.82	20.31	39.27
Zn	21.94	84.75	39.41	47.4	39.6

Net Values = Reported Value - (acid and water blank values)

Table 8.--Summary of hydrologic data available from Glacier National Park activities

Field Site	Period of Record[1]	Precipitation	Stream Stage	Stage/Discharge
Toad Valley	1981-1982	Yes[2]	Yes	Yes[3]
Martha's Basin (Site 1)	1981	No	Yes (?)	Yes[4]
Martha's Basin (Site 2)	1982	No	Yes	Yes[3]

[1]The hydrologic field seasons were: August 19 to September 16, 1981, and August 9 to September 12, 1982. The short field seasons are dictated by the long winters in Glacier National Park.

[2]The 1982 field season is currently the only period of continuous precipitation record.

[3]Three stage/discharge values are available.

[4]One stage/discharge value is available.

conditions existing during other portions of the year.

The above discussion of hydrologic data gathered in Glacier National Park is based solely on information collected during the limited field seasons of that region. Analysis of these data can be made more complete and quantitative if additional information is obtained to:

1. Define the meteorological character of the region, especially regarding the type of precipitation events that occur during the summer

2. Extend the precipitation record by comparison with data from a local or regional, full-time recording station

3. Estimate the annual contribution of water from snowmelt.

DISCUSSION - POLLUTANT DATA

The air data from Glacier National Park (table 3) show some of the lowest trace element values recorded on the continental United States. Davidson and others (1983) reported values for lead in Olympic National Park of 2.2 ng/m^3. Fox and Ludwick (1976) reported atmospheric lead values at Quillayute, Washington, ranging from 2.3 ng/m^3 to 32 ng/m^3. The lower value represented air masses arriving at Quillayute after transit for several days over the northern Pacific Ocean. Davidson and others (1980) reported lead values of 0.9 ng/m^3 for Hotel Everest View in Nepal, cadmium values less than 0.04 ng/m^3, and silver values less than 0.05 ng/m^3. Zoller and others (1974) reported lead values at the South Pole of 0.63 ng/m^3, and copper of 36 ng/m^3. The above information supports the assertion that the Glacier National Park atmospheric trace element values are probably representative of global background values for the same elements.

Sulfate values from Martha's Basin were from two successive sampling periods. Their average is 1.1 µg/m^3. This is probably what one could expect from a relatively clean site. Alkezweeny and others (1982) reported sulfate values over the Seney National Wildlife Refuge in Northern Michigan of 0.7 µg/m^3 to 1.2 µg/m^3. Barnes and Eggleton (1977) reported sulfate values for Pendeen, England, when wind was from maritime sources, of 1.9 µg/m^3 and less. Therefore, the sulfate levels found in Martha's Basin are representative of relatively clean air masses. Similar conclusions can be drawn about nitrate values measured in the park.

Three types of vegetation were collected. Results for subalpine fir and woodrush are shown in table 5 and for moss in table 4. Normally, trace element values in vascular plants are rather variable. However, moss tends to give fairly reliable trace element results. The major reason for this was postulated by Tyler (1972). He indicated that an ion exchange occurred on the surface of moss plants. Therefore, airborne trace elements landing on them tended to absorb into the plant rather than adsorb to the plant surfaces.

One technique of helping to determine probable sources of trace elements in the atmosphere is through the use of enrichment factors. Normally, enrichment factors are used for calculating relative quantity of a trace element in the atmosphere in relationship to some average crustal values (Rahn 1976). However, the technique can be used to compare other media and has been applied to moss and litter results. Local soils can be used, but for consistent results, the soils should have undergone complete digestion. Soil results in this paper are acid extractions and, therefore, Taylor crustal values were used for comparison (Taylor 1964). The enrichment factor is calculated according to the following formula:

$$EF = \frac{C_x / C_{Al}}{C_{x_{source}} / C_{Al_{source}}}$$

Where C_x is the concentration of any element in the medium of concern, C_{Al} is the concentration of aluminum in the compared medium; $C_{x_{source}}$ is the the concentration of the element of concern in the potential source medium; and $C_{Al_{source}}$ is the concentration of aluminum in the same medium.

Moss concentrations for a series of trace elements were compared to Taylor crustal values. These trace elements are not known to have long-term transport characteristics. In other words, they are not normally enriched in air relative to crustal sources. Table 9 shows that for crustal elements, all have enrichment factors less than 10 with the exception of manganese; 10 is considered an approximate breaking point between being enriched (>10) and not being enriched (<10) (Duce and others 1975; and Alkezweeny and others 1982). This implies that, in general, the moss plants have ratios of these elements about equal to what one would expect if there were crustal sources for these elements. Similar results obtained when moss is compared to air indicate that a good deal of the measured concentration of elements in moss merely comes from resuspended local crustal materials.

Basin ranged from 19.4 for copper to 250 for lead. In Toad Valley they ranged from 14.1 for zinc to 933 for lead. In both locations, lead had by far the highest enrichment factor and Toad Valley lead enrichment factor was over three times greater than Martha's Basin. However, QA results show that the lead values for Toad Valley may be unrealistically higher. Therefore, the difference between sites may not be as large as it appears.

When moss is compared to air for the elements considered to be enriched in the atmosphere, virtually no enrichment was found. In this case, one can hypothesize that the lead, zinc, and copper had as a possible source the atmosphere, and the enrichment of these elements in moss resulted from the deposition of airborne particles and eventual absorption into the plant. These elements were also enriched in the atmosphere (Davidson and others 1983) in Glacier National Park. This indicates sources were not crustal in origin. A strong probability exists they were anthropogenic in origin. The exception is cadmium. Cadmium at Martha's Basin is definitely highly enriched over crustal values. However, the atmosphere seems to be about 33 times more enriched in cadmium than moss. Explanation for this is not apparent at this time.

Table 9.--Enrichment factors for moss using Taylor crustal values for comparison in soil and measured atmospheric values for comparison in air*

	Martha's Basin		Toad Valley	
	Moss/Soil	Moss/Air	Moss/Soil	Moss/Air
CRUSTAL				
Magnesium	6.9	3.4	7.6	2.2
Manganese	51.1	1.5	34.5	2.4
Calcium	7.6	1.2	2.6	1.0
Iron	2.5	0.3	3.2	4.0
Sodium	8.4	0.3	12.3	4.8
Titanium	4.0	No air data	6.2	No air data
ENRICHED				
Cadmium	165.0	0.03	None detected in moss	None detected in moss
Copper	19.4	None detected in air	22.7	None detected in air
Lead	250.0	0.6	933	7.3
Zinc	29.0	None detected in air	14.1	0.3

*Because of difficulties with Toad Valley air data, data from PoleBridge, another exposed site in the Park, were used.

This relationship holds for both Martha's Basin and Toad Valley. However, the situation changes for those elements generally considered in the literature to be enriched in the atmosphere. Enrichment factors were calculated for these elements in moss compared to Taylor crustal values (table 9). Here enrichment factors in Martha's

Litter is an important part of a forest ecosystem. It is an active site for trace metal accumulation and eventual movement into the mineral soil (VanHook and others 1977); it is also intimately associated with soil. Table 10 shows that, in general, elements in litter considered to be crustal had no enrichment over what would be

Table 10.--Enrichment factors for litter using Taylor crustal values for comparison in soil and measured atmospheric values for comparison in air*

	Martha's Basin		Toad Valley	
	Litter/Soil	Litter/Air	Litter/Soil	Litter/Air
CRUSTAL				
Magnesium	3.6	1.8	5.5	1.6
Manganese	65.8	1.9	23.7	4.7
Calcium	7.7	1.3	3.4	1.3
Iron	2.1	0.3	1.7	2.2
Sodium	2.8	0.1	3.1	1.4
Titanium	3.0	No air data	3.6	No air data
ENRICHED ELEMENTS				
Cadmium	1218	0.22	617	0.8
Zinc	31.2	None detected in air	21.2	0.4
Lead	263.0	0.6	305	2.4
Copper	14.9	None detected in air	17.3	0.4

*Because of difficulties with Toad Valley air data, data from PoleBridge, another exposed site in the Park were used.

expected when compared to Taylor values. The exception, as in moss, was manganese. Also, no enrichment was found when compared to air values. Again, one can hypothesize that the litter is reflecting entrapment by vegetation of resuspended locally derived material. It also reflects some direct mixing of mineral soil material with organic material.

Elements considered to be enriched in the atmosphere are also enriched in litter at both sites when compared to Taylor crustal values. Lead again is more enriched at Toad Valley. Cadmium shows much greater enrichment for Martha's Basin than in Toad Valley. This was demonstrated by Davidson and others (1983) for air samples collected at Martha's Basin. These had an enrichment factor for cadmium of 5400 compared to 790 for cadmium at the Polebridge site.

When litter values were compared to air values, no enrichment was noted. Again, one can hypothesize that the primary source of the enriched elements in litter is from atmospheric deposition of wet, dry, and atmospheric particles intercepted by trees and eventually washed off or dropped with dead organic material onto the forest floor.

CONCLUSIONS

Trace element levels and sulfate and nitrate values in the atmosphere of Glacier National Park, in general, reflected current literature estimates or background levels for these compounds. However, moss and litter samples from both sites were enriched when compared to earth crustal values for lead, cadmium, copper, and zinc. The source of these elements in both moss and litter was postulated to be atmospheric deposition.

Obvious differences between the exposed and remote sites are not apparent. Judgment on the relative exposure of the two sites will have to wait until 1983 data are analyzed and detailed statistical analyses can be performed.

Finally, it was shown that remote sites (up to 30 km from road) can be instrumented for hydrological studies and maintained. All this information will aid in setting up a true background monitoring site at Olympic National Park, a designated U.S. Biosphere Reserve.

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COST-EFFICIENT BASELINE INVENTORIES OF RESEARCH NATURAL AREAS

Edward O. Garton

ABSTRACT: A cost-efficient approach to baseline inventories of research natural areas has been forced on us by the scarcity of funding for such surveys. Such an approach requires the use of cost-efficient survey methods and application of a particular strategy. The elements of this strategy must include a systematic team approach, a careful definition of objectives, and a continuous effort to simplify all aspects of the work.

INTRODUCTION

Research natural areas (RNA) in the Northern Rocky Mountains represent a valuable source for knowledge of the functioning and dynamics of natural populations, communities, and ecosystems There is a real need for inventories of these areas so that they can be used for basic research, for comparison to managed areas, and for long-term studies of stasis and change. But how is this to be accomplished in the face of declining funds for research in the natural resource fields? One solution is to wait for more funds to become available. Another is to begin the work without delay by applying the most cost-efficient methods available. This paper is an attempt to suggest a strategy for this approach and some conclusions from applying it to the Bannock Creek Research Natural Area in the Boise Basin Experimental Forest, Idaho.

A COST-EFFICIENT STRATEGY

Conducting a cost-efficient survey depends as much upon a proper strategy as upon particular methods. The elements of this strategy must include a systematic team approach, a careful definition of objectives, a continuous effort to simplify and the use of cost-efficient survey methods. These elements must be combined with all the other characteristics of objective scientific research for a baseline survey to be successful.

A systematic approach is essential in cost-efficient surveys because limited funding makes errors or omissions disastrous. Scientists with the International Biological Programme (IBP) made an initial effort to systematize basic inventory efforts by developing a check sheet to be completed for all present and potential IBP natural areas (Peterken 1967; Clapham 1980). Ohlman (1973) utilized the IBP check sheets and added a checklist of steps for gathering vegetation data in temperate forest research natural areas. The checklist in table 1 should help in developing a systematic procedure for inventorying all the components of research natural areas.

Baseline inventories, by definition, must gather basic information for all components of the natural ecosystems surveyed, including characteristics of the topography, soil, geology, climate, weather, hydrology, terrestrial and aquatic vegetation, and terrestrial and aquatic fauna. This will not be possible unless a team approach is taken, relying upon experts in the various fields. Although most or all of the field work must be performed by technicians to reduce costs, the design, planning, analysis, and evaluation must be done by a team of experts.

The most critical element of a cost-efficient strategy for inventorying research natural areas involves carefully defining the objectives of the inventory. The objectives for each research natural area must be defined individually based upon the significance of that particular area both locally and regionally. Does this forested RNA contain relatively undisturbed stands that would be ideal to compare to the surrounding intensively harvested forest? Does this area include habitats, species, or features that are unique within the region? What is most important about this area? To reach a final definition of objectives, we must weigh the significance of specific components against the value of characterizing all of the components in some detail and reach some workable and justifiable compromise. This will only be successful if we force ourselves to simplify and to be realistic as to what can be accomplished with the available resources of people and funds.

Once the objectives have been defined, methods can be chosen to obtain the information necessary to meet those objectives. The most efficient methods that just meet the objectives must be chosen. In general, these will be extensive rather than intensive methods. They will measure physical, structural, or time-specific characteristics of the components rather than rates or dynamic characteristics. Only when particular species or communities are of particular

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Table 1.--A checklist of steps for inventorying research natural areas

___ 1. Obtain establishment report for the RNA.
___ 2. Gather USGS topographic maps, aerial photos, soil maps, geological maps, vegetation maps, etc.
___ 3. Contact agency, university. and private personnel to obtain all available information on characteristics of the RNA, its prior history, and studies carried out there.
___ 4. Carry out a preliminary classification of the RNA into vegetation types.
___ 5. Identify features of particular significance.
___ 6. Make a preliminary definition of objectives of the inventory.
___ 7. Request necessary permits and permissions.
___ 8. Conduct a preliminary reconnaissance of the RNA, accompanied by local people with most knowledge of the area, if possible.
___ 9. Revise objectives of the inventory and send them out for review.
___ 10. Summarize characteristics of the RNA from all information gathered under each category below:
  - ___ a. Topography
  - ___ b. Soil
  - ___ c. Geology
  - ___ d. Weather and climate
  - ___ e. Hydrology
  - ___ f. Terrestrial vegetation
  - ___ g. Terrestrial fauna
  - ___ h. Aquatic flora
  - ___ i. Aquatic fauna

___ 11. Map homogeneous units (vegetation types, stream sections, etc.) identifiable on aerial photos for use as survey strata.
___ 12. Finalize objectives.
___ 13. Verify that all necessary permits and permissions are obtained.
___ 14. Design data gathering procedures to meet objectives for each component.
  - ___ a. Select methods.
  - ___ b. Design data forms and code book.
  - ___ c. Plan data analysis in detail.
  - ___ d. Consult with an applied statistician.

___ 15. Conduct preliminary survey to do the following:
  - ___ a. Revise map of strata based on ground reconnaissance.
  - ___ b. Gather sample data for each method where it is not already available.

___ 16. Complete study design.
  - ___ a. Analyze preliminary sample data to estimate variances.
  - ___ b. Determine sample sizes, work-hours, costs, etc.
  - ___ c. Revise design as necessary, deleting objectives, reallocating effort and funds.
  - ___ d. Consult with an applied statistician.

___ 17. Conduct field work.
  - ___ a. Insure quality control.
  - ___ b. Revise methods if necessary.

___ 18. Analyze data.
___ 19. Write up results of inventory and distribute as appropriate.
___ 20. Write up recommendations for further work and for follow up.
___ 21. Deposit all specimens in museum and herbarium collections.
___ 22. Deposit all data, reports, descriptions of field procedures, forms, code books, and methods of data analysis in two different repositores (one local and one regional).

significance will intensive methods be justified for those components at the expense of detail in other components.

INVENTORY APPROACH

Cost-efficient baseline inventories must take an approach quite different from intensive ecosystem studies such as the biome programs of the IBP or the intensive studies of particular components typically conducted on experimental forests or grasslands. Certain aspects of this approach, as outlined in the checklist (table 1), need to be emphasized. It is essential to gather every shred of information already available before gathering any yourself. This is the cheapest way to obtain information and for some components it may be all that can be obtained in a cost-efficient survey. As information accumulates repeatedly revise the objectives and delete those that are not feasible. Do not accept any information obtained uncritically. Evaluate and validate it where possible. Get all the free help possible from specialists and pay for it where necessary. This may be more cost-efficient than trying to obtain the information with untrained assistants. Do not overlook the necessity of obtaining permits and permissions. Obtain information from studies on similar areas and/or conduct a pilot survey of all field methods to obtain sample data on variation in characteristics, cost and work-hour requirements of methods. Finally, consult an applied statistician during the design phase and just prior to conducting the field work.

INVENTORY METHODS

There are generally a wide array of methods available to gather information on any particular component of a natural ecosystem. The methods differ in their level of detail, bias, precision, and time/cost requirement. At one extreme are broad scale, reconnaissance, index methods that produce information lacking in detail and precision, often with large potential for bias. Cost-efficient surveys must utilize methods closer to this end than to the other extreme of methods

applied to individual species, requiring large numbers of replications and repeated samples through time, and often entailing costly laboratory analyses of samples. The methods can be grouped and rated on their applicability to cost-efficient surveys on the basis of the characteristics that they measure (table 2).

Table 2.--Cost-efficiency rating of methods available to inventory characteristics of research natural areas

Characteristic	Cost-Efficiency Rating[1]
Topography	
Contour map	1
Elevation (range and median)	1
Profile graphs	1
Classification of drainage patterns	1
Landform map	2
Numerical description of drainage networks	
Stream orders	2
Stream density (number/area)	2
Drainage density (length/area)	2
Channel and lake basin descriptions	
Stream gradient	2
Channel cross-sections (width, depth, shore water depth, pool characteristics)	4
Pool-riffle ratio	4
Basin cross-sections (width, depth, volume)	4
Soils	
Soil map	
Reconnaissance map of general patterns of soil occurrence	1
Detailed survey map of individual soil units	4
Site map of all variations on local site	5
Soil profile of sample points	
Field description of horizons, thickness, color, and gross structure	1
Lab tests of particle size distribution, structure, bulk density, specific gravity, and porosity	4
Moisture characteristics (moisture content, infiltration rates, field capacity, and avaliable moisture capacity)	4
Soil temperature profile	4
Geology	
Large-scale geologic characteristics of the region	1
Reconnaissance survey of surface and exposed subsurface characteristics	3
Detailed subsurface survey	5

Table 2.--Cont.

Characteristic	Cost-Efficiency Rating[1]
Climate, weather, and hydrology	
Large-scale climatic characteristics (mean min. and mean max. monthly temperatures, mean precipitation, frost-free period)	1
Incident solar radiation	4
Atmospheric conditions	
Air temperature (minimum, maximum)	3
Humidity	4
Barometric pressure	4
Windspeed and direction	4
Cloud cover	4
Airborne particle content	3
Gaseous content (especially pollutants)	3
Hydrologic characteristics	
Evaporation and transpiration rates	4
Precipitation (rain and snowfall, snow depth and condition, pH)	3
Runoff and channel flow	4
Water conditions (temperature, light penetration, turbidity, color, pH, alkalinity, hardness, conductivity, dissolved oxygen)	3
Terrestrial vegetation	
Vegetation maps	
PI (photo interpretation) units	1
Cover types based on brief reconnaissance	1
Habitat types based on ground reconnaissance	3
Habitat type-seral stages based on ground reconnaissance	4
Structural characteristics	
Forest trees	
Frequency	1
Basal area	2
Crown closure	2
Stand table (density/basal area in dbh classes)	2
Height distribution	2
Stock table (volume in dbh classes)	4
Leaf area index	4
Shrubs, tree saplings, herbaceous vegetation, grasses, and seedlings of woody plants	
Frequency	1
Density	2
Cover	2
Biomass	4
Dynamic characteristics	
Accretion (growth in size of individuals)	4
Regeneration	4
Phenology	5
Colonization	5
Morbidity	5
Mortality	4

Table 2.--Cont.

Characteristic	Cost-Efficiency Rating[1]
Terrestrial vegetation (cont.)	
Dynamic characteristics (cont.)	
Removal by consumption and harvest	5
Net production	5
Woody debris	
Biomass of litter and duff (if not sampled in soil survey)	2
Size distribution and biomass of larger material	3
Rates of accumulation and decay	4
Terrestrial fauna	
Taxonomic groups	
Small birds	2
Small mammals	2
Reptiles and amphibians	3
Upland birds	3
Arthropods	3
Furbearers	3
Raptors	3
Large mammals	3
Large carnivores and bears	5
Population and individual characteristics	
Presence (species list)	1
Relative abundance (site to site)	2
Home range size	3
Diet	3
Density	3
Sex ratio	4
Age structure	4
Survival	5
Fecundity	5
Immigration	5
Emigration	5
Aquatic flora	
Forms that may be sampled as a group	
Planktonic forms	2
Submerged vegetation	3
Floating vegetation	3
Emergent vegetation	4
Characteristics	
Presence (species list)	2
Relative abundance (site to site)	3
Absolute abundance (biomass)	4
Phenology	5
Losses	5
Production	5
Aquatic fauna	
Forms that may be censused as a group	
Planktonic forms	2
Macroinvertebrates	2
Amphibians	3
Fish	3
Aquatic mammals	4
Aquatic birds	3

Table 2.--Cont.

Characteristic	Cost-Efficiency Rating[1]
Aquatic fauna (cont.)	
Characteristics	
Presence (species list)	1
Relative abundance (site to site)	2
Diet	4
Density	4
Sex and age structure	4
Survival	5
Fecundity	5
Immigration	5
Emigration	5

[1]Cost efficiency rating:
- 1=Very cost efficient; should be done in general.
- 2=Moderately cost efficient; generally will be done.
- 3=Fairly cost efficient; may be done.
- 4=Expensive; should be done rarely.
- 5=Extremely expensive and time consuming; almost never feasible.

Topography

Most of the topographic information that is feasible to gather for a RNA will come from USGS topographic maps (7½ min series) and widely available aerial photographs at scales of 1:12,000 to 1:24,000. A contour map is readily drawn from a USGS topographic map using a pantograph, mapograph, or similar device. This can serve as a base map for all other maps. The elevation range and profile graphs can also be produced from USGS topographic maps. Aerial photos can be used to classify drainage patterns, draw a land form map and obtain the simpler numeric information describing drainage networks and lake basins (table 2).

Soil

Reconnaissance maps of the general patterns of soil occurrence have been drawn by the USDA Soil Conservation Service (SCS) for most areas of the U.S. with agricultural potential. It will rarely be possible to gather more information on the distribution of soil types than is contained in the maps and reports prepared by the SCS. If such maps are not available for the area including the RNA, a decision will have to be made whether their value justifies the cost of preparing them for the RNA. Detailed soil descriptions should be made at each site where terrestrial vegetation is sampled, however. These descriptions will generally need to be restricted to field descriptions of the soil profile sampled with an auger.

Geology

Extremely high costs preclude anything more than a gross characterization of the geology of RNAs.

Climate, Weather, and Hydrology

Weather and hydrologic conditions at any site must be sampled repeatedly through time because of their nature and daily and yearly cycles. It will not often be possible to obtain more information than what is available from the National Weather Bureau or published studies. In occasional cases where atmospheric or hydrologic conditions are of particular significance, it may be possible to sample air temperatures, air pollutants, precipitation, or water conditions in particular seasons (see table 2 for details).

Terrestrial Vegetation

Mapping vegetation patterns within a RNA is an essential first step in designing a sampling scheme for both plant and animal communities. Mapping photo interpretation (PI) units is possible from moderate scale aerial photography. Fairly detailed PI units can be identified on large scale (about 1:4000) photos and may justify their expense if the RNA is within short flight time of an airport where a commercial aerial photographer operates. Photos at this scale provide a valuable record of the distribution of larger plant species and plant communities. A brief ground reconnaissance can provide sufficient information to convert this PI unit map into a cover type map. If a habitat type classification system is available for the area, and resources allow, it would be preferable to conduct a more thorough ground reconnaissance and map habitat types.

The vegetation types mapped will form the strata from which to select sample points to characterize the vegetation quantitatively. If only one or two samples can be drawn, then these should be located subjectively by picking areas to sample that are most representative of the vegetation type. However, it is much better to draw a number of randomly located samples from each stratum. There are a large variety of approaches available for sampling vegetation (Mueller-Dombois and Ellenberg 1974), but I recommend using nested permanent plots. Permanent plots are desirable so that plots can be remeasured later to begin studying dynamic aspects of the vegetation. Nested plots of varying size are needed to sample the different vegetation strata (trees, shrubs, grasses, forbs, and seedlings of woody species). On the Bannock Creek RNA, K. Pregitzer used a system consisting of a 0.1 hectare circular plot in which all living and standing dead trees greater than 10 cm dbh were tagged, heights estimated with clinometer, and diameters measured, a concentric 375 m^2 plot in which plant canopy coverage was estimated for all vascular plants, a concentric 50 m^2 plot in which tree regeneration less than 10 cm dbh was counted, and 28 microplots (0.5 m x 0.5 m) in which plant coverage and shrub basal diameters and heights were recorded (Garton and others 1983). Downed woody material was surveyed using Brown's (1982) procedures. Measurements at a number of permanent plots like these in each vegetation type provide estimates of the structural characteristics, frequency, basal area, dbh distribution, height distribution and cover for trees and frequency, density and cover for shrubs, tree saplings, herbs, grasses, and seedlings of woody plants. It will rarely be feasible to gather more that this in cost-efficient inventories. Estimates of dynamic characteristics (table 2) will require resurveying these permanent plots at a later time. Photographic records of each plot could be very useful during followup surveys and require little expenditure in time and funds. It should be noted that no attempt to measure below-ground characteristics of the vegetation seems feasible in cost-efficient surveys.

Terrestrial Fauna

Sampling all of the taxonomic groups of terrestrial animals is not possible on an RNA larger than a few hectares. The first decision must be which groups to survey. The decision should be based upon the importance of information for each group from this RNA and the ease with which the information can be obtained. Small territorial birds and small mammals are the two groups most efficiently sampled during the early summer breeding season. Reptiles, amphibians, upland birds and select groups of arthropods (defoliating lepidoptera, ground beetles, etc.) may sometimes be sampled. Furbearers, raptors, large mammals, large carnivores, and other arthropods will be too costly to census in general.

Obtaining information on the presence, relative abundance, and density of the selected animal groups is generally feasible on a limited budget, but more detailed information (table 2) is not. On Bannock Creek RNA, I found transect methods (Emlen 1971; 1977) to be 50 percent more efficient than variable circular plots (Reynolds and others 1980) for estimating density of small birds. We were able to sample small birds in four stands and small mammals in one stand during this survey (Garton and others 1983). Relative indices of abundance for all other animal groups are more efficient than absolute density estimates (Caughley 1977). Estimates of other characteristics of terrestrial animals (table 2) can only be undertaken for individual species of special importance such as rare species. Caughley (1977), Davis (1982), Schemnitz (1980) and Seber (1983) describe these methods. Such work will probably preclude censusing any other terrestrial animals in cost-efficient inventories, but may be justified in some cases.

Aquatic Flora

Studies of aquatic flora are time consuming and costly and can only be undertaken if the aquatic resources are of particular significance on the RNA. Such work will rarely be able to provide more information than a species list and estimates of relative abundance at reasonable cost (table 2).

Aquatic Fauna

Aquatic fauna must be treated in a manner similar to terrestrial fauna. Macroinvertebrates, micro-invertebrates, and fish are the groups most easily sampled (table 2). Estimates of relative abundance are the most detailed characteristics that are feasible to obtain in cost-efficient inventories. Platts and others (1983) provide a guide to sampling methods for aquatic communities. F. Rabe surveyed the invertebrates on the main trunk of Bannock Creek, a third order stream, with seven permanent stations at which debris dam, pool, and riffle habitats were sampled (Garton and others 1983)

COST

Cost-efficient, baseline inventories of research natural areas are feasible as long as it is recognized that they cannot provide a comprehensive and complete inventory of the characteristics of the area. Cost efficient inventories of research natural areas the size of Bannock Creek RNA (about 200 hectares in area) should not be undertaken for less than $15,000. This level of funding was allocated as follows in the Bannock Creek RNA Study: $4,000 to sample terrestrial vegetation, $5,000 to sample aquatic invertebrates, $5,000 to sample small birds and mammals, and $1,000 to coordinate the project and prepare study plans and reports. It would have required about $30,000 to sample the structural characteristics of the components in a comprehensive manner, and substantially more than that to estimate dynamic characteristics of even a few components. Taking the approach outlined here, it will probably take $10,000 to $15,000 per 100 hectares to conduct a cost-efficient inventory of a typical RNA.

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SOME STATISTICAL ASPECTS OF BASELINE MONITORING

IN RESEARCH NATURAL AREAS

Gordon D. Booth

ABSTRACT: Two main topics on baseline monitoring are discussed. First, the CUSUM chart is introduced as a means of detecting departures from the norm. And second, the periodogram is introduced as a means of detecting cyclical patterns in research natural areas (RNA) data.

INTRODUCTION

Many aspects of baseline monitoring in research natural areas (RNA's) are statistical. The statistical procedures described here, though not presently used in baseline monitoring of RNA's, have definite potential.

An important aspect of any monitoring program is, or course, the establishment of a baseline. In many cases, it is not easy to define this line for a specific study. Without a clear definition of what constitutes the baseline, it is impossible to know when conditions have departed from it--either within the same research natural area or in some other area for which the RNA was to serve as a control.

Some statistical methods appear well-adapted to application in monitoring research natural areas. For example, techniques common in acceptance sampling could be applied easily to RNA monitoring.

Because monitoring is based on repeated measurements taken over time, we are really observing what statisticians call a time series. Some of the procedures used in the study of such series of measurements have the potential of yielding unique, useful information. For example, what are the magnitudes of seasonal variations in the variables being measured? Are there other nonseasonal cycles? If so, how frequently do they occur? How strong are they? Answers to these questions can lead to an understanding of the underlying physical relationships and can guide the researcher to seek explanations that otherwise would not have been sought.

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THE CUSUM CHART

Often the purpose of monitoring the baseline is to help us (1) determine whether some characteristic of the RNA has changed, or (2) whether a characteristic of some other area has changed. Both objectives require criteria for judging when a real change has taken place.

Industrial quality control is that branch of industry that deals with the quality of the finished product. Several statistical techniques help assure that products of poor quality are not released. Some of these techniques involve repeated sampling of a production process, taken at different times. This type of quality control is called acceptance sampling, and several of its methods can be modified for application to the monitoring of an RNA.

One of the methods used in acceptance sampling is the Cumulative Sum Chart, or CUSUM chart. The procedure involves repeated sampling at intervals over time. Each sampled result is used to plot a point on a special chart. If the plotted values show a pattern that indicates a change in the underlying system, the monitoring method declares the system "out of control." In the case of a research natural area, we could monitor levels of pollutants, species diversity, soil conditions, or any of many other characteristics of interest.

The CUSUM chart is a simple graph of the cumulative departures from a target value. The target can be selected by the investigator or it may be mandated by law. The principle of the CUSUM chart is based on the fact that, if we keep adding departures from the target value, the positive and negative deviations will cancel one another. Therefore, the cumulative sum will hover near zero. This is true if the system being monitored is centered on the target value. On the other hand, if a real change takes place in the system, the cumulative sum will steadily depart from the zero line--either above or below.

The CUSUM chart is easy to use and effective. To illustrate its use, data from Hall and others (1980) will be studied. The data represent calcium concentrations measured for 32 weeks. The measurements were made at a fixed site on a stream. After the measurement was made for week 6, acid was added 120 m upstream from the measurement site. These data are plotted in figure 1.

The acid spill simulates a precipitation event of high acid concentration that enters the stream through runoff. From figure 1, we see an upward trend in the data. This would indicate an increase in calcium concentration.

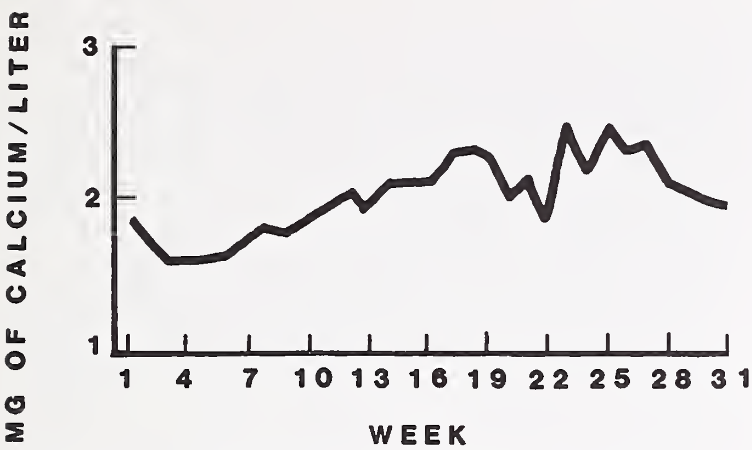

Figure 1.--Calcium measured downstream from the site of an acid spill that occurred after the measurement was taken for week 6. Units are milligrams of calcium per liter.

However, if we were monitoring the calcium baseline in the stream, our interest might be in detecting the change in concentration as early as possible. We would not have the advantage of hindsight as illustrated in figure 1. At what week would we be willing to conclude that a real increase in calcium concentration had taken place? And if so, when did it occur? If we had data only up to and including week 13, would we feel comfortable claiming an increase in calcium concentration had taken place? Probably not.

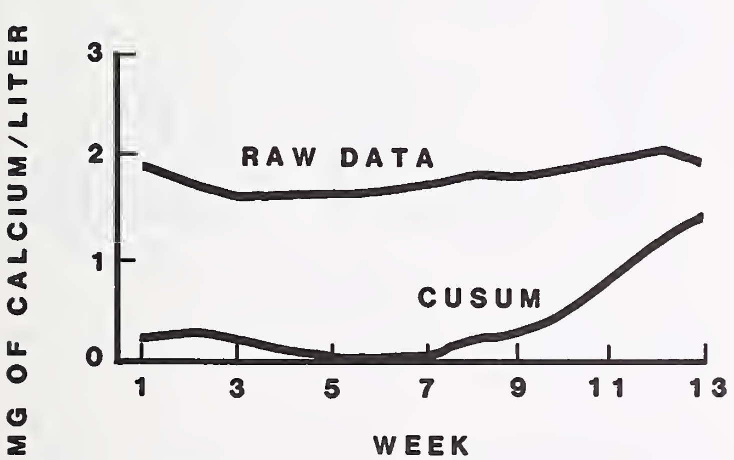

Figure 2.--Comparison of information available from raw data and from a CUSUM chart of the calcium concentration data from Hall and others (1980).

Figure 2 allows us to compare the monitoring information contained in the raw data with that contained in the CUSUM chart for the first 13 weeks. During this period it would be difficult to detect any real trend in the raw data. Nevertheless, if we had been monitoring with the CUSUM chart, we would have suspected a change as early as week 10 and would have been even more convinced by week 11. By week 13 we would have been almost certain, and furthermore, we would suspect that the change took place at about week 7.

This example illustrates the basic characteristics of the CUSUM chart. First, it is particularly sensitive to departures from a reference value. Second, it is possible to tell at approximately what point in time the change took place. And third, early detection is possible. The thing to look for in a CUSUM chart is a change in slope. Obviously, such a change took place at about week 7. Even as late as week 13, the effect of the acid spill was not at all evident in the raw data.

CUSUM charts have many facets to their use and construction. There are methods (Grant and Leavenworth 1980; Duncan 1974) available for determining when the CUSUM chart indicates a real change in the baseline.

The CUSUM chart provides one of the most straightforward methods of monitoring a baseline, and it should find wide application in research natural areas. The same method could also be used in long-term monitoring with less frequent measurements. However, the continuously decreasing cost of automated data collection devices may make more frequent sampling in RNA's a common occurrence.

CYCLICAL PATTERNS

Data obtained from monitoring should almost always be plotted against time to reveal important information. For example, on a graph, time trends become apparent and seasonal cycles are usually clearly visible. However, other important cycles often are not visible at all. Nevertheless, these other cycles can provide us with invaluable information concerning underlying phenomena. For instance, the presence of hidden cycles can greatly influence observed values in a monitoring system. The failure to take such cycles into account could cause us to attribute normal cyclical behavior to some other not-real source.

The Search for Cycles

The methods of searching for periodic (that is, cyclical) behavior in data fall into the general heading of Fourier analysis, or as it is sometimes called, harmonic analysis. This is a set of techniques for describing data in terms of periodic components. When certain cyclical patterns are found to exist, in addition to the expected seasonal ones, it should encourage the researcher to investigate potential underlying causes. Without knowledge that nonseasonal cycles exist, underlying causes would never be sought. Many of the data obtained through monitoring programs lend themselves to Fourier analysis.

The Periodogram

One of the main tools in the search for cycles is the periodogram, a chart showing frequencies and how strongly they are represented in the data. These frequencies refer to the number of times a cycle occurs during the time the sample was taken. For example, if we sampled for 90 days, a frequency of 2 would refer to a cycle that occurred twice during the 90 days. A frequency of 3 would mean the cycle repeated three times during our sampling period.

A cycle is represented on a graph as a peak followed by a valley. Therefore, a cycle repeated many times would have evenly spaced peaks. The time from the crest of one peak to that of the next peak is called the "period" of the cycle. A bar chart that emphasizes the presence of cycles with different frequencies or periods is called a periodogram. If the bar that corresponds to a given frequency is high, a cycle of that frequency is present in the data. There are methods available for determining how high the bar must be to have confidence that the cycle is real.

The power of the periodogram comes from its ability to untangle the component cycles, when several cycles are superimposed. In such cases, visual inspection of a graph often fails to reveal the true periodic components.

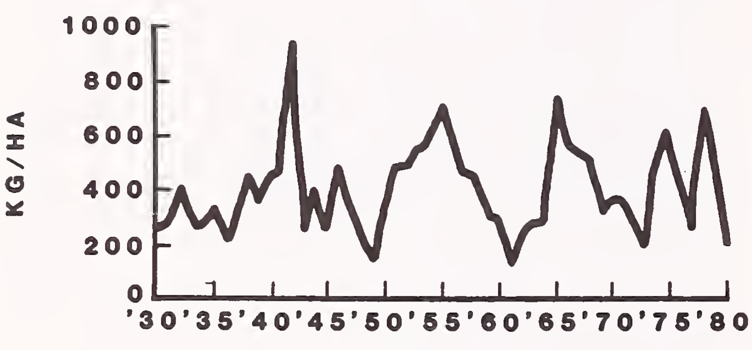

Figure 3.--Herbage yield data from Hanson and others (1982). Units are kilograms per hectare.

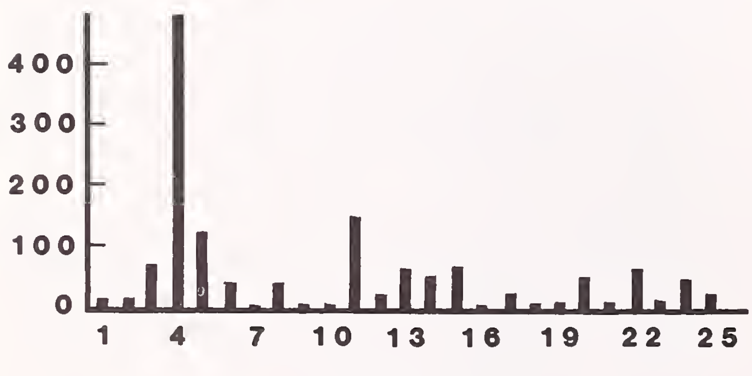

Figure 4.--Periodogram of herbage yield data from Hanson and others (1982).

Hanson and others (1982) discuss herbage yield over 51 years. The raw data are shown in figure 3. The authors did not discuss the cyclical aspects, but some cycles are evident in the periodogram of their data (fig. 4).

Although some form of periodicity is obvious in the raw data, the exact nature of the cyclical components cannot be seen easily. From the periodogram, there is an obviously influential cycle with a frequency of about 4. This means the cycle repeats four times during the 51 years sampled. To obtain the period of the cycle we simply divide the frequency into the number of years sampled. This gives a period of 51/4 = 12.75 years. Therefore, there is a strong cyclical component in the data that repeats about every 12 to 13 years. Another periodic component in the data appears at a frequency of about 11, which corresponds to a period of about 4.6 years. This second component is weaker, and may not be real. Nevertheless, the data are suggestive of a cyclical pattern occurring about every 4 to 5 years.

It would be reasonable for the investigators to seek possible explanations for both the 12- to 13-year and the 4- to 5-year cycles. Because herbage yield can be dramatically affected by available moisture, it might be worthwhile determining whether cycles of similar periodicity are present in precipitation data.

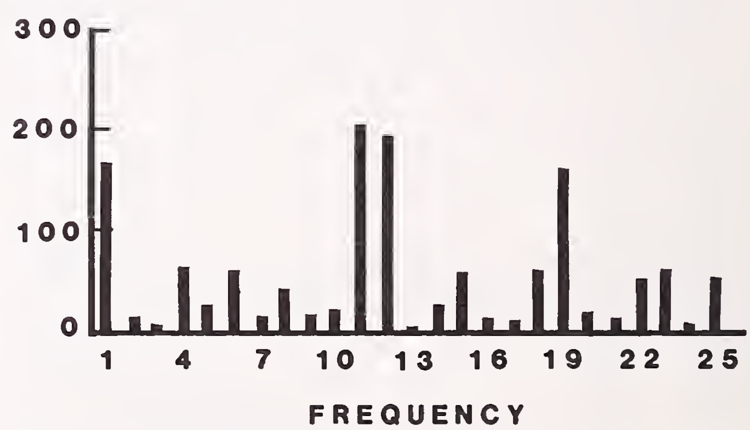

Figure 5.--Periodogram of precipitation data from Finklin (1983). Units are inches.

Finklin (1983), for instance, presents precipitation data for the same time span, but for an area several hundred miles away. The periodogram for the precipitation data is presented in figure 5. We do not find a precipitation cycle with a period of 12 to 13 years (that is, a frequency of about 4), but we do find one of 4 to 5 years (corresponding to a frequency of about 11). Should we attribute the 4- to 5-year herbage yield cycle to precipitation? While we do not propose to answer that question here, the basic tools for suggesting questions and answers are

available in the periodogram. Interestingly, cycles of about 11 years are common in precipitation data, although none was found in this case. It should also be noted that for a meaningful study, we should have considered precipitation data from the same geographical area as the herbage data. Unfortunately, such data were not readily available.

The theory of the periodogram includes confidence intervals and tests. It provides us with a method of discovering cyclical behavior of the characteristic being monitored. Failure to recognize such cycles and to make allowance for them can lead to false conclusions. For instance, if an increase is observed in the characteristic being measured, we need to know that it is not a regularly occurring cyclical pattern. Otherwise, the increase in the monitored value could cause unwarranted management action.

Frequency of Measurement

In the study of any time series such as the monitoring of a research natural area, a key question is, How often should measurements be taken? The full answer is too extensive for inclusion here. However, several basic concepts will be discussed.

If monitoring takes place on a yearly basis, any cycles with periods shorter than 1 year will, obviously, be missed. For example, if measurements were made each May it would be impossible to study seasonal patterns. There would be no data available at any time of year other than May. If we want to study patterns with periods shorter than 1 year, we should sample several times each year and at the same times each year. For instance, if we want to study seasonal patterns we should take monthly, weekly, or daily readings rather than annual ones. It would be inappropriate to sample in February in some years and in March in others, because it could lead to an inaccuracy that could easily mask all but the strongest patterns in the data.
Sampling should be made at equally spaced intervals of time.

Another basic concept is that of an alias frequency. Due to the rate at which samples are taken (that is, the sampling rate), some frequencies are indistinguishable from others, thus are aliases of one another. If a value is monitored at short intervals, it is more likely that important frequencies will be detected free of their aliases. However, frequent sampling is more costly. Bloomfield (1976) discusses aliases in detail.

Intervention Analysis

While the periodogram emphasized the frequency of cycles in the data, another approach emphasizes the ability to predict future values based on historical patterns. The emphasis is on the variable time and how measurement errors at one instant are related to those at other times. Attempts are made to measure the relationship of errors at one time to those errors that precede it. The methodology is described best by Box and Jenkins (1976), and was developed by them over several years.

One application of the Box-Jenkins method involves the evaluation of the effects of an intervention into a system being monitored. It addresses the question of whether a measurable change took place as a result of a known intervention. It also answers questions concerning the nature and magnitude of such changes. The procedure is described by Box and Tiao (1975). They have named the method Intervention Analysis and have given extensive examples in the framework of ozone monitoring in downtown Los Angeles.

Intervention analysis can be of considerable value in studying the effects of known interventions on the monitored area. Changes in laws and regulations in areas far removed from a research natural area can have dramatic effects on the monitored site within the RNA. Often the exact date of a policy change is known. It remains to determine whether the research natural area has been affected, and if so, by how much. Intervention analysis can be a useful tool.

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IMPORTANCE OF BASELINE INFORMATION TO

THE RESEARCH NATURAL AREA PROGRAM

Russell M. Burns

ABSTRACT: The Forest Service has knowledge gained from establishing research natural areas for almost 60 years. It found that baseline information essential for all monitoring activities is costly to accumulate. One relatively inexpensive method is suggested. Increasing scarcity of pristine representative examples mandates that each use of an area be carefully planned so that the RNA's will not be lost to future generations of researchers.

The Forest Service has been involved in the research natural area program for more than 55 years. It all started with a 1912 Act of Congress that directed the Secretary of Agriculture to select, classify, and segregate lands within the National Forests that were suitable for homestead entry. In compliance with the provisions of that Act, Forest Ranger J. A. Frieborn in 1926 examined a 4,464 acre tract of land adjacent to the Mt. Lemmon Recreational Area on the Coronado National Forest in Arizona. He found it to be not valuable for agriculture and, therefore, not subject to segregation under the Act. However, the lands were viewed as having value for timber production and streamflow protection and to contain cover of such a character that it would be in the public interest to keep the area in its present state so that the flora could be studied by the Natural History Society of Tucson, Arizona, and other scientific organizations. Accordingly, on March 23, 1927, Acting Secretary of Agriculture R. W. Dunlap issued a Land Classification Order designating the tract of land as the Santa Catalina Natural Area. The order stated that the natural area was to be "so managed as to permit scientific studies of forest growth." The Forest Service had its first research natural area.

At last count there were approximately 440 research natural areas (RNA's) administered by eight Federal land managing agencies. Coordination of the national program among agencies is through the Federal Committee on Ecological Reserves (FCER). A Directory of Research Natural Areas on Federal Lands of the United States of America authored by the FCER and published in 1977 listed 389 RNA's located in 46 States and one territory, totaling about 4.4 million acres. The primary emphasis at that time was to identify and establish new areas so as to capture representative areas before they were utilized for other purposes, and their pristine condition was lost. This remains one of our principal objectives. However, the objective is not solely to assemble a collection of pristine areas. Research natural areas are meant to be used, and unless they are used, a collection of areas in and of itself serves no useful purpose.

Listed in the directory are the two primary purposes for developing a comprehensive and representative system of research natural areas. The first is "to preserve a representative array of all significant natural ecosystems and their inherent processes as baseline areas." The second is "to obtain through scientific education and research, information about natural system components, inherent processes, and comparisons with representative manipulated systems." The collection of baseline data, monitoring ecological change, and monitoring effects of resource management are all goals of the program.

We have heard about various types of monitoring activities being conducted in the Northern Rocky Mountain States and in the Pacific Northwest and for a short time were able to vicariously share the problems and accomplishments of the speakers. It is gratifying, indeed, to hear that our research natural areas are being utilized and that monitoring is under way. The RNA program may have had its genesis in 1927 but it has only been in comparatively recent times that many of the RNA's have been used for monitoring.

Baseline data are needed for virtually every purpose to which RNA's are put. These data are <u>essential</u> for monitoring of every sort. Therefore, it would seem logical to assume that establishment of an RNA would be contingent upon gathering this information, and that resources for this task would be part and parcel of the formal designation process. Unfortunately, this is not true in the Forest Service nor do I believe it to be true in any of the seven other land-managing agencies.

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Furthermore, no matter how laudible and practical the collection of baseline data may sound, it is not likely to become true in the near future.

There are several reasons why there should be no conditions restricting the establishment of new RNA's. Probably most important is that such a provision would scuttle or at least seriously undermine the entire RNA program. In the Forest Service portion of the network we have 149 RNA's. However, we do not as yet have even one example of 62 of the 145 forest types listed by the Society of American Foresters. And of the 83 forest types that we do have represented, we have only one example of only 28, which means that for these 28 forest types there is no insurance against catastrophic loss. We need redundancy. In the best of times, RNA's are not high priority items in Agency, Regional, or Forest budgets. In times of budgetary constraint even fewer RNA's are established. Any impetus gained through the realization that pristine examples of a representative type are becoming scarce at an increasingly rapid rate is lost if financial stipulations, such as those mandating gathering baseline data, are placed on establishing new RNA's.

How then can we get the monitoring phase of the RNA program moving without seriously impeding establishment of new areas? One thing we can continue to do during these times of tight budgets is to complete the network and introduce redundancy into the RNA system. Another is to convince prospective users of RNA's of the importance of systematically acquiring, recording, and sharing baseline data. But probably the most profitable thing we can do is to demonstrate the importance of RNA's to prospective user groups and thereby gain their support either in financing the work or in actually gathering the data.

There is a large prospective user group out there that has either never heard of RNA's or that is not fully aware of the potential use and advantage to which RNA's can be put. They must be contacted and be made aware. Within the Forest Service the largest potential user of RNA's and the one that should benefit most from their use for monitoring is our National Forests. The National Forest Management Act (NFMA) of 1974 requires monitoring of all resource management activities to insure that no permanent damage is done to the productivity of managed sites. The Act does not, however, mandate that the monitoring be done on RNA's. It may be done on any suitable site. Therefore, it behooves those of us in the Forest Service to demonstrate the advantages of using RNA's in lieu of other areas for monitoring if we want support and resources from our National Forests.

Advantages of using RNA's for monitoring are manifold. They include:

o - the convenience of not having to locate new areas each time a new activity is to be monitored

o - lower costs because baseline data collected for monitoring one activity is equally applicable for monitoring other activities

o - increasingly broader application as the data base is expanded

o - greater accuracy as the data base is continuously updated and refined

o - use of the RNA as a forum wherein researchers and their administrative counterparts may cooperate in projects of mutual concern and benefit

We should be able to look to outside sources for assistance as well. RNA's are established for approved, nonmanipulative research and education by qualified users or user-groups. All costs of locating, establishing, protecting, and administering RNA's are borne by the land management agencies. The land management agencies are the principal beneficiaries of their use, but they are not, or need not be, the sole beneficiaries. Opportunity exists for involving the university community to a greater extent. Grants and cooperative agreements are two vehicles whereby the agencies may tap the expertise and trained resources of our research counterparts in academia and enable them to participate more fully in the process--to our mutual benefit. From the amount of monitoring we heard about earlier, there certainly must be other strategies for gaining support for this work. If anyone has a successful method I would welcome hearing of it so that I may share it with others, nationwide.

Before we all rush out and start gathering baseline data or start making arrangements to have it done, I would like to voice some words of caution. A great deal of time, money, and effort has gone into identifying and establishing each research natural area. This investment is meant not only for the present generation of researchers and educators but, more importantly, for many generations of users yet to come. Let us be certain that we pass the RNA's on in as good a shape as when we first established them. This means that when we gather baseline and monitoring data we employ those methods that have the least adverse impact on the RNA. Researchers tend to be under self-imposed deadlines and schedules to get a job done and for this reason often employ an expeditious rather than a less harmful and more time consuming action or method, a soil pit, for example, instead of a bore hole.

When next you are out on an RNA preparing to undertake some nonmanipulative research, ask yourself if a less harmful method may be employed. If there is one, use it, regardless of the added time or inconvenience involved. We do not have the luxury of doing less and moving on to a comparable area. There may not be one.

RNA's are not ours to abuse, not even in the slightest. Consider each as you would a threatened species, and treat it accordingly. Let us not number ourselves among those who hunted the last of the carrier pigeons or destroyed the habitat of the ivory-billed woodpecker. It is becoming increasingly unlikely that we will ever find, and be able to reserve, such pristine representative areas again.

Section 2. Successful Monitoring Programs

INTEGRATING ACADEMIC AND AGENCY RESEARCH INTERESTS AT THE H. J. ANDREWS EXPERIMENTAL FOREST

Arthur McKee

ABSTRACT: A large number of studies are conducted at the H. J. Andrews Experimental Forest and seven nearby research natural areas (RNA's). During 1983, 63 academic and 21 agency scientists were involved in 56 separately funded projects. In addition, 48 graduate students used the areas. Data from various monitoring efforts were used in 79 of the total number of studies, including 21 studies conducted on RNA's. Several factors appear responsible for the success of the monitoring program that combines academic and agency research interests. The factors are: a vigorous research program, common research interests and goals, a spirit of cooperation among the scientists, a coordinating administrative structure, clearly defined responsibilities, and a centralized data bank.

INTRODUCTION

The H. J. Andrews Experimental Forest was established in 1948 by the U.S.D.A. Forest Service for the purpose of examining the effects of different logging methods on forest regeneration and water quality. Because hydrologic and forest successional studies require long-term measurements, monitoring efforts were started along with the earliest research. During the 1950's and 1960's scientists initiated several meteorological, forest succession, erosion, and nutrient cycling studies.

Many of these studies collected data of a long-term nature, or provided the basis for establishing a long-term monitoring program. The Andrews Forest, by which term the seven nearby research natural areas are collectively included with the H. J. Andrews Experimental Forest, was selected in 1970 as an intensive study site by scientists of the Coniferous Forest Biome (U.S. International Biological Program) because of the existence of the rich data base.

The research program at the Andrews Forest changed dramatically in two significant ways as a result of this selection. The first of these changes was the shift from nearly exclusive use of the site by U.S.D.A. Forest Service scientists to use by a cadre of researchers affiliated with agencies, universities, or both. That shift has continued to this day, with the proportion of university scientists and research projects gradually increasing to where they now predominate (table 1). About two-thirds of all research projects in 1983 were funded through various universities. Concomitant with this shift has been an increasing and substantial use by graduate students (table 2). The second significant change was the development of multidisciplinary ecosystem studies by scientists of the Coniferous Forest Biome project, which integrated both agency and university research. This prompted the creation of a coordinated monitoring program to provide the necessary long-term data sets of common interest to this diverse group.

Large, interdisciplinary research projects are the dominant type of research conducted today at the Andrews Forest. In addition, there are several smaller projects addressing specific problems. Studies of both types contribute to, and rely on, the monitoring program. Since its inception during the Coniferous Forest Biome research, the monitoring program has enlarged in scope and improved in organization. Its success appears to be the result of several factors.

DISCUSSION

The reasons for long-term ecological data collections are manifold and the utility of such data is increasingly recognized. Data collected by a monitoring program provide a measure of the natural variation in an ecosystem and permit an examination for long-term trends and changes. Such data facilitate analyses of ecosystem processes and development of ecological theory. They make possible an accurate assessment of the effects of anthropogenic pollutants. If more data were available, environmental impact statements would have more credibility, and regional and local land-use plans could be more effectively developed by the land manager. For these reasons and others, Gene Likens, past president of the Ecological Society of America, argues that the establishment of long-term studies and high-quality monitoring programs is a major priority for ecological research (Likens 1983).

A significant part of the difficulty in establishing a monitoring program is deciding what factors or components of the ecosystem should be measured. What data sets will be most useful in the future? Several conferences were sponsored by the National Science Foundation in the late 1970's to address that question (Botkin 1977, 1978; TIE 1979a, b). The reports provide lists of suggested measurements but offer little advice on how to establish and maintain a monitoring program. The following discussion

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Table 1--Number of research projects at the H. J. Andrews Experimental Forest and nearby research natural areas during 1983

	Number of research projects			
Subject area[1]	University	Agency	Total	Utilizing monitoring program
Animal ecology	6	3	9	3
Ecosystem processes	16	5	21	11
Entomology	17	3	20	3
Fisheries	1	1	2	2
Genetics	1	1	2	2
Geology	3	3	6	3
Hydrology	1	2	3	3
Limnology[2]	7	0	7	5
Plant ecology	8	4	12	9
Silviculture	6	9	15	10
Soils	0	1	1	0
Totals	66	32	98	51

[1]Within a subject area, the numbers of university funded projects, agency funded projects and projects utilizing the monitoring program are presented with total number of projects.

[2]Including riparian ecology.

Table 2--Number of graduate student projects at the H. J. Andrews Experimental Forest and nearby research natural areas during 1983

	Number of graduate student projects			
Subject area[1]	University	Agency	Total	Utilizing monitoring program
Animal ecology	2	1	3	2
Ecosystem processes	8	0	8	4
Entomology	5	0	5	2
Fisheries	4	0	4	2
Geology	1	2	3	2
Hydrology	0	2	2	2
Limnology[2]	3	0	3	3
Plant ecology	7	2	9	4
Silviculture	4	2	6	3
Soils	2	0	2	2
Tree physiology	3	0	3	2
Totals	39	9	48	28

[1]Within a subject area, the numbers of university funded projects, agency funded projects and projects utilizing the monitoring program are presented with total number of projects

[2]Including riparian ecology.

offers some advice based on the experience gained in developing the monitoring program at the Andrews Forest. Although each site will have its own unique needs and problems, there appear to be some common factors or key ingredients in a successful program. By fostering the development of these common factors, a group interested in long-term monitoring will be a long way toward resolving what to measure and how to maintain the program.

The common factors of a successful monitoring program are: (1) a diverse and vigorous research program; (2) common research goals or interests; (3) a spirit of cooperation or willingness on the part of researchers to share responsibilities and data; (4) an administrative structure to coordinate the monitoring activities; (5) clearly defined responsibilities for collection and maintenance of data; and (6) a central data bank. Stable financial support is a major factor, but if all the other ingredients are there, the financial issues become largely a matter of coordination.

The first factor listed--a diverse, vigorous research program--is perhaps the most important ingredient for success. The mixture of research projects at a site will, to a large extent, determine the measurements to be made and should provide the basis for the logistical and financial support. By coordinating the needs and resources of the various research projects, economies of scale emerge and responsibilities can be delegated. Monitoring activities that are not integral parts of research programs and have to stand on their own accomplishments will have a more difficult time competing for limited research funds.

The research program at the Andrews Forest is large and diverse. During 1983, 63 academic scientists, 21 agency scientists, and 48 graduate students worked in 56 separately funded projects. The varied nature of the research is shown in table 1, which divides the 56 separately funded projects into subprojects by subject area. Table 2 shows the variety of graduate student projects. The existing monitoring program at the Andrews Forest (table 3) has been determined by the long-term research needs of previous and current scientists. That it is an important part of the overall research effort is obvious from tables 1 and 2, which show that 51 of the 98 research projects and 28 of the 48 graduate students utilized data from the monitoring program in 1983. Twenty-one of the 79 projects that used data from the program were located on research natural areas. The components or factors presented in table 3 include all those recommended in the TIE (1979b) report listing core requirements for a long-term ecological research program. The monitoring program at the Andrews Forest has grown in step with the increased diversity of research projects and would be far less complete with a smaller research effort.

Table 3 also shows the relative responsibility of agency and university research projects for the different components. Many factors are being measured by both groups and the data sets merged. This reveals the degree to which research interests are held in common by agency and university scientists. It also indicates the spirit of cooperation among the scientists because the data collected become freely available to all.

A large monitoring effort clearly needs to be coordinated. The coordination of monitoring activities at the Andrews Forest was first done in an informal manner with principal investigators pooling resources and data from their own research projects. The research activities had increased so much by the mid-1970's that this informal type of coordination was proving impractical. In 1977, the administrative structure shown in figure 1 was established and has since proven effective. The site manager has primary responsibility for the coordination of the monitoring program. The questions of what components or factors to measure, methods to be used, and frequency of sampling are addressed by the Local Management and Policy Committee. This committee is composed of both university and agency scientists who have research projects at the Andrews Forest. The committee also provides the continuity necessary to maintain a long-term ecological measurements program derived from research projects that ordinarily have a limited time span.

The Local Management and Policy Committee also helps define who is responsible for the different measurements. This is important in a program of this magnitude where several projects may have an interest in a data set, but for reasons of efficiency just one or two projects may be conducting the sampling. Along with the site manager, the committee helps maintain quality control by specifying the standards to be met.

The last of the common factors for a successful monitoring program is a central data bank. Other terms sometimes used for central data bank are data management center or quantitative services group. All data sets collected as part of a monitoring effort should be well documented, carefully edited, and readily available. The experience at the Andrews Forest has been that a well supported data bank, staffed with qualified people who are dedicated to data management, is essential. The monitoring program at the Andrews did not work well during the period when individual investigators were responsible for editing and archiving their own data. The standards of documentation varied greatly from researcher to researcher but generally were inadequate. Delays were common in obtaining requested data. A gradual appreciation of the benefits of having a central data bank resulted in the development and establishment of our current facilities.

Table 3--A summary of the monitoring program at the H. J. Andrews Experimental Forest and nearby research natural areas showing relative responsibility of agency and university research projects for each component

Component or factor monitored	Collected or measured by agency	Collected or measured by university
Site description and background:		
Historical record	A	U
Geologic maps	A	U
Soils maps	A	u
Flora	A	U
Fauna	a	U
Meteorological and physical:		
Shortwave radiation	a	U
Net allwave radiation	a	
Air temperature	a	U
Water temperature	A	U
Dewpoint		U
Wind speed		U
Wind direction		
Precipitation	A	U
Snow depth and duration	a	U
Soil water content	A	u
Groundwater level	a	U
Watershed discharge	A	U
Erosion and sediment load	A	U
Stream morphology	A	U
Streamwater transparency		
Ice cover of stream		
Chemical measurements:		
Atmospheric--		
Wetfall	a	U
Dryfall		U
Particulates		
Gases		
Terrestrial--		
Vegetation	a	U
Litter (including heavy metals)	a	U
Soil	A	U
Soil solution	A	U
Aquatic--		
Streamwater	A	U
Litter	a	U
Vegetation		U
Invertebrates		U
Primary production and decomposition:		
Terrestrial--		
Leaf area index	a	U
Standing crop (including phenology)	A	U
Litterfall		U
CO_2 release from soil		
Carbon Retention	a	U
Aquatic--		
Phytoplankton		u
Periphyton	a	U
Macrophyte		U
Carbon retention	A	U
Population records:		
Terrestrial--		
Plants	A	U
Amphibians		u[1/]
Birds		u[1/]
Mammals	a	u[1/]
Aquatic--		
Zooplankton		u
Benthos		U
Fish	a	U

Capital letters denote a greater responsibility than lower case. The listing includes all components recommended by TIE, Institute of Ecology (1979b) for a long-term ecological measurement program.

[1/]Component is not being sampled at frequency or level recommended by TIE (1979b) report.

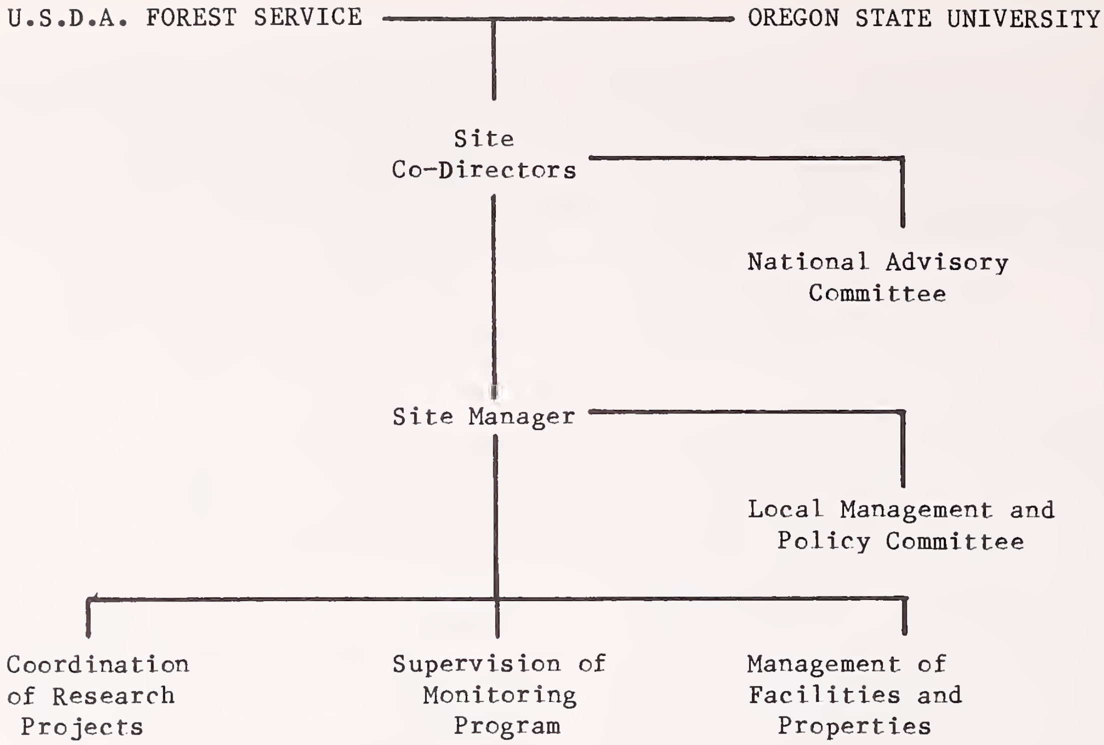

Figure 1.--The administrative structure of the research program at the H. J. Andrews Experimental Forest and associated research natural areas.

Data are now readily available, with the assurance they have been carefully edited and are well documented. The data management people also provide statistical analyses, assist in experimental design, and help the scientists with a variety of quantitative services.

The data bank has grown beyond the immediate needs of the scientists working at the Andrews Forest and is now a center for data management of several departments at Oregon State University. Its own success is a reflection of the value of the services it performs. This is not meant to suggest that each site needs such a large investment in a data bank. The message is clear, however, for any monitoring effort: do not ignore the needs and costs of maintaining quality data and have someone in charge of documenting, entering, and editing the data.

CONCLUSION

The monitoring program at the Andrews Forest developed over several decades, evolving from a sampling program that was quite limited in scope to the large, coordinated program of today. Research interests have always determined the monitoring program that has provided the long-term ecological measurements of common interest to scientists.

Several factors have contributed to the successful establishment of the program. These are probably common to any similarly successful monitoring effort. The factors are: a vigorous research program, common research interests and goals, a spirit of cooperation, a coordinating administrative structure, a clear definition of responsibilities, and a centralized data bank. Some of these are intangibles and difficult to establish. A spirit of cooperation and common research goals are not off-the-shelf items. They require considerable care in nurturing and, once established, require continual attention. In a program of this magnitude coordination would be impossible without cooperation.

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BIOLOGICAL MONITORING: THE NATURE CONSERVANCY'S PERSPECTIVE

Steven C. Buttrick

ABSTRACT: The Nature Conservancy works to protect natural diversity through a balanced program of identification, land protection, and management. Biological monitoring is an important component of the Conservancy's management program. Because monitoring can be very resource consumptive, the decision to monitor is made conservatively. The Conservancy initiates a monitoring program for four reasons: 1. to fulfill legal obligations, 2. to determine responses to management practices, 3. to track threats, and 4. to measure overall protection goals. In all cases the focus of the monitoring is the element (rare species or community) and not the preserve or natural area.

INTRODUCTION

The Nature Conservancy is a nonprofit private conservation organization committed to the preservation of natural biological diversity. The Conservancy works to accomplish this goal through a balanced program of identification, land protection, and management. Identification involves the selection of species and communities most in need of protection and is primarily accomplished through state-based inventories called Heritage Programs. To date, these inventories have been established in 35 states to identify which species and communities are rare or endangered and to locate the best occurrences of these. This identification process provides the information needed to make land protection decisions. Land protection involves bringing critical habitat under some form of legal protection. But land protection, whether through registration, conservation easement or fee acquisition, cannot alone assure the long-term preservation of the species or communities of interest. These critical elements are still subject to ecological changes such as succession and various disturbances both natural and anthropogenic and thus can require management attention. The Nature Conservancy's stewardship program is responsible for providing adequate management for the species and communities that occur on Conservancy preserves and are both endangered and in need of management. "If we fail in this task, the identification and protection efforts that preceded it have been wasted" (Blair 1983).

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Resources (including money, time, and personnel) available for conservation are extremely limited. The Conservancy effectively uses its resources by concentrating protection efforts on only those species and communities most in need because of rarity or threat. The stewardship program applies this same orientation to its management activities. This is done by focusing resources on elements that are not only rare but will also benefit from our efforts.

Monitoring, the identification and measurement of change over time, can play an important part in any biological management program, by identifying when management intervention might be needed and tracking the success of management actions. Monitoring, however, can involve a large commitment in time, labor, and money and thus warrants careful consideration before being initiated.

The Nature Conservancy has been trying to use biological monitoring as a cost effective tool on its preserves by seriously considering the policy questions of why monitor, what to monitor, and when to monitor. At the present time the topic of how to monitor has not been adequately addressed. The policy issues must be resolved first to ensure that monitoring programs are addressing the right questions and are only developed when the information is needed to further Conservancy goals.

WHY MONITOR?

The first question to be addressed is: Why monitor? The Conservancy will begin a monitoring program for four reasons.

To fulfill legal obligations.—Occasionally, the Conservancy will lease certain rights of a preserve such as haying or grazing to a second party or receive a piece of property encumbered with a lease or restrictive covenants. In such cases the Conservancy must monitor because of a legal need to determine whether rights retained by an original owner or leased by us to a second party are adversely affecting the elements we are seeking to protect. Monitoring and baseline data collection must be detailed and accurate because the information generated must be able to stand up in a court of law.

To determine responses to management practices.--The second major reason for the Conservancy to initiate a monitoring program is to assess the effect of our management practices on the species and communities of interest. The Conservancy begins this process by evaluating the management needs of all rare elements on its properties. Based on these needs preserve management decisions are made. Because very little is known about the ecological requirements and associated management needs for the majority of rare species and communities, it is often necessary to monitor the effects of a particular management treatment or to conduct research designed to identify the treatments that are most effective in maintaining or improving the condition of the rare element in question.

To track actual or potential threats.--Threats that we might wish to keep track of include pesticide drift from adjacent lands; exotic or feral species; agricultural run-off including silt, pesticides and fertilizers; water drawdown from heavy agricultural or residential use; water pollution from upstream actions; and even acid rain. Many of these threats should be addressed prior to any land protection effort because they could affect the overall viability and defensibility of the element to be protected at the site and thus affect the overall design of the preserve.

To measure progress toward overall protection goals.--The final reason to monitor is to measure the overall success of our protection efforts. As stated earlier, the Conservancy works by protecting habitat for the most endangered species and maintaining the best representative examples of the country's natural communities. These species and communities can be looked at as biological investments that the Conservancy has made. In this context, the major function of biological monitoring is to determine whether these investments are maintaining their value over time. This type of monitoring is a simple auditing function, asking whether species populations protected on Nature Conservancy preserves are increasing, decreasing, or stable over time, or whether protected communities are recovering, stable or changing due to succession or other natural or anthropogenic processes. Another objective is to serve as an early warning system to notify us of needed management intervention.

WHAT AND WHEN TO MONITOR?

The focus of all biological monitoring within The Nature Conservancy is the element, that is, the endangered species or community protected on a preserve. Each of the four reasons to monitor is centered around protected elements. We monitor, then, important species and communities protected on our preserves, indicators of these elements, conditions necessary for their maintenance, and specific threats to these elements.

The important point to be made here is that the focus of the monitoring is not the preserve or natural area. In the past general preserve monitoring was occasionally carried out. This monitoring, whether done quantitatively through transects and quadrats or on a more qualitative basis through photo points, was often done simply to detect change without any clear motive or intent. Similarly, monitoring to determine community dynamics or ecosystem function unassociated with management needs, although of great importance, is peripheral to The Nature Conservancy's goal of element preservation. Although the Conservancy will not direct its resources to nonelement centered monitoring, it does actively encourage use of its preserves by academic institutions and individuals interested in conducting short- or long-term ecological research. Nature Conservancy preserves such as California's Santa Cruz Island, Northern California Coast Range Preserve, and Mexican Cut in Colorado have extensive research and monitoring programs being carried out by government and academic researchers.

Within The Nature Conservancy's portfolio there are approximately 800 preserves encompassing 400,000 acres over which we have direct management responsibility. These preserves contain well over 3,000 populations and stands of endangered species and communities. The Conservancy does not have the resources needed to monitor all these elements, at least in any quantitative fashion. To address, specifically, which elements will be monitored, when and how, the Conservancy must apply the principle of triage. According to the American Heritage Dictionary of the English Language, triage is defined as a system designed to produce the greatest benefit from limited treatment facilities for battle-field casualties by giving treatment to those who may survive with proper treatment and not to those with no chance of survival and those who will survive without it. The same concept can be applied to any similar system used to allocate a scarce commodity or resource only to those capable of deriving the greatest benefit from it. To make the decision for when and what to monitor the following factors should be considered: element selection, demonstrated need, and element manageability.

These factors have to be considered at two levels: which elements most need and will benefit by monitoring and which occurrences of these elements (populations or stands) most need and will benefit.

Element selection is critical because not all species and communities protected by the Conservancy are equally endangered or threatened. The Conservancy has developed a procedure for assigning importance or endangerment ranks to elements. These ranks take into

consideration taxonomic uniqueness, total distribution, total number of occurrences protected and unprotected, ecological fragility, threat, and persistence. High-ranked elements and specific threats to high-ranked elements should receive first consideration when allocating monitoring resources.

Establishing a demonstrated need to monitor is a more difficult factor. In its preserve management planning process the Conservancy addresses this question each year on an element by element, preserve by preserve basis, the results of which are stored and managed in a computerized data base. High-ranked elements, protected on our preserves that are not currently threatened or whose response to active management is well known, receive a low monitoring priority. Seral communities and endangered species restricted to these communities warrant monitoring consideration as well as those elements where the need for active management has been identified but responses to different management practices are unknown. In the majority of cases very little is known about habitat requirements or management needs of high-ranked elements. Before initiating monitoring or research programs, the Conservancy attempts to pull together known management related information about a particular species or community, file it in a centralized element file, and summarize it in a newly developed computerized document called an Element Stewardship Abstract. The abstract is a synthesizing document serving three important functions. First, it identifies information gaps and targets future research efforts. Second, it provides a standard format for highlighting the specific information about a species or community that helps determine its management needs. Finally, it allows the Conservancy to readily communicate management information among different preserves, state offices, regional offices, and Heritage Programs. In this way we avoid duplicative research while increasing our management capabilities.

The third factor, manageability, is a pragmatic one. It forces us to ask whether we should monitor a particular occurrence of an element if we already know that we either cannot successfully manage it or do not wish to manage it. An example of the latter situation is an old growth white pine stand in Connecticut. Here we are dealing with an over-mature seral community and the decision would probably be made to let succession take its course. Documenting the demise of this magnificient stand through constant monitoring might be of academic interest but it does not appreciably further our goal of natural diversity preservation.

While many species and communities may warrant monitoring, certain protected occurrences of them (populations and stands) may not. Many populations of endangered species protected in the past are simply inviable due to low population levels or habitat alteration. Similarly, many stands are so degraded that restoration is not feasible or cost effective. Inviable or indefensible populations or stands should not be allowed to drain limited conservation sources. The Nature Conservancy's new preserve selection and design procedures attempt to prevent low-quality occurrences from entering the Conservancy's portfolio.

MONITORING METHODOLOGY.

The last topic I wish to consider is monitoring methodology. The Nature Conservancy has a very liberal view on what qualifies as biological monitoring. To us, simply noting on a regular basis the presence or absence of a particular element does constitute a low level of monitoring. It is very important that the level or intensity of monitoring reflect the importance of the element being monitored and the objective of the monitoring program. Thus, clear goals should be established before any monitoring program is established. Depending on the goals, the reasons for monitoring, and the importance of the element, the monitoring can either be qualitative or quantitative. Qualitative monitoring includes noting the presence or absence of an element on a regular basis and can be accomplished by any person, regardless of scientific training, who has the ability to identify the element in question. Permanent photo points sampled on a periodic basis also represent a level of qualitative monitoring frequently carried out on Nature Conservancy preserves. More detailed information can be collected using standardized field survey reports on a regular basis. During the preserve design phase of a protection project, field survey forms should be completed for each of the important elements we are seeking to protect. These forms are used to record basic abiotic, population, and compositional data that can serve as a baseline and can be used to compare the data recorded on field survey forms during subsequent visits to the site. At the present time most high-ranked species and communities on Conservancy preserves receive at least this level of monitoring through use of an extensive volunteer network. This qualitative monitoring can supply sufficient information to allow the Conservancy to measure the status of protected elements throughout its portfolio and often to alert us to potential management problems.

When more detailed data is needed, quantitative monitoring is preferred; but as the monitoring scheme increases in complexity so does the demand for time and financial commitment. A simple census can be used for many plant and animal populations. Because we are dealing with rare species, frequently all individuals of a population can be counted easily and different measurements made on each individual or certain tagged ones. When dealing with communities or larger populations, permanent plots and transects are often employed. Monitoring designs cannot be standardized, but must be tailored to fit the monitoring goal and the nature of the species,

community, or environmental factor being studied. The most intensive monitoring schemes are used when detailed, reproducible statistics are required.

The following section describes a few biological monitoring programs that illustrate some of the reasons for monitoring described in the beginning of this paper as well as different levels of monitoring intensity.

EXAMPLES

A detailed monitoring program is warranted when the data generated must be able to stand up in a court of law. The Katharine Ordway Sycan Marsh Preserve in Oregon is a case in point.

This 24,000 acre preserve, acquired in 1980, came encumbered with a 40-year grazing lease that stipulates that the condition of the marsh can not be degraded. The area was acquired to protect, among other things, upland sandpipers, sandhill cranes, and outstanding examples of communities of Cusick's bluegrass and tufted hairgrass. The major question for preservation of the area was whether the important species and communities for which the marsh was protected were changing or being degraded due to grazing and irrigation practices. In 1982 the Conservancy collected the necessary baseline information to establish the condition of the marsh (TNC 1982), and concurrently set up a monitoring system to document any changes in the baseline. Because the magnitude of the marsh precludes monitoring each community in each pasture and all faunal species of concern, it was decided that a few communities and a couple of bird species would best serve as indicators of change due to irrigation and grazing.

The tufted hairgrass community was emphasized in the sampling because it contained species of high palatability, contained dominant species of caespitose growth form (caespitose species are thought to reflect grazing utilization impact better than rhizomatous species), was widespread, in a relatively high ecological condition, and would reflect significant changes in ranching practices. The communities were quantitatively described using a series of permanent transect clusters. Each cluster contained three permanent 25 m transects located in parallel at 3 m intervals. Total basal area, density, and size class distribution of caespitose grass basal tufts were measured in 20 X 50 cm microplots spaced at 1 m intervals along each transect. Frequency for all species was calculated using 7.07 X 7.07 cm loops spaced at 0.5 m intervals. To compare grazed with ungrazed transect clusters, two micro-exclosures (50 X 15 m) and two macro-exclosures (130 ha and 65 ha) were established and sampled. A sampling schedule has been set up to monitor any changes in the baseline.

To monitor the effects of ranching practices on the bird fauna of Sycan Marsh, two species were chosen as indicators, the black tern (Chlidonias niger) and the sandhill crane (Grus canadensis tabida). Black terns require surface water of varying characteristics throughout their reproductive cycle and represent the r-selection life-history pattern. Sandhill cranes require a diversity of habits ranging from open water for resting to tufted hairgrass communities for foraging and represent the K-selection life-history pattern.

In order to make marsh management inferences based on black tern population dynamics, in 1981 and 1982 baseline data were collected to determine the number of breeding black terns on Sycan Marsh, to document the hydrologic and vegetative characteristics of the nesting habitat, to determine reproductive success, and to describe habitat utilization. Similarly, baseline data were collected to determine the number of breeding pairs of sandhill cranes, to describe nest-site characteristics, to determine nesting success, the impact of research disturbance on nesting success and the annual recruitment to the fall flock. Each year the terns and cranes will be censused and their reproductive success assessed.

Monitoring to assess the effect of management practices on species and communities is well illustrated by the Conservancy's management research program at the Edge of Appalachia Prairies in Ohio. In 1959 The Nature Conservancy acquired Lynx Prairie, one of E. Lucy Braun's study areas, and the first of a series of preserves in Adams County, Ohio. Since then the Conservancy and the Cincinnati Museum of Natural History have added The Wilderness, Hanging Prairie, Buzzardroost Rock Preserve, and Abner Hollow, collectively called the Edge of Appalachia Preserve System. These preserves are significant because of the prairie openings they protect along with a complement of important prairie plants. Ohio prairie openings, once estimated to cover 2.5 percent of Ohio's landscape (Troutman 1979) are now reduced to about 100 acres (Cusick and Troutman 1978). The most obvious threat to the protected prairies is from woody species invasion, a problem well documented by aerial photographs taken from 1938 to 1971 (Annala and Kapustka 1983). Because of their geographic location, small size and unique habitat, prairie management techniques that are applicable to prairies in Iowa, Minnesota, or even other areas of Ohio may not be applicable in Adams County. In 1983, The Nature Conservancy and the Cincinnati Museum of Natural History developed a management research plan to evaluate a variety of management techniques on these prairie openings. The management goal is to reduce forest encroachment by removing invading woody species and to improve the overall quality of the prairies, especially as sites for rare and endangered plant species.

The research and monitoring plan briefly discussed below, is described in detail by Hirsh (1983). Three management treatments and one control are being used. The management

treatments are (1) March burns on a 2-year cycle, (2) June burns on a 2-year cycle, and (3) woody plant cutting. Sixteen prairie openings are being studied. Each treatment will be applied to four prairies. Rare plants, key prairie species, woody invaders and the prairie community in general will be monitored over a 4-year period to judge the effectiveness of the treatment methods. For rare plants, 13 species are being monitored. Twenty individuals were tagged on each of the 16 prairies and measured for height, aerial diameter, basal diameter, number of flowering stems, and number of seeds produced. Eight typical prairie species (four grasses and four forbs) are being monitored. Sixteen individuals per species per prairie have been marked and measured for height, basal diameter and number of flowering stems. Similarly, 16 individuals of four woody invaders have been marked and are being monitored for mortality, growth, and resprouting in each of the prairies. Quadrats are being used to monitor treatment effects on the community cover and physiognomy. Ten randomly placed, 1-m^2 quadrats are being used on all 16 prairies to record percent cover of all grasses combined, all forbs combined, all woody plants combined, and bare ground and general physiognomy. In all four cases (communities and rare, key, and woody species) the data were collected at three times during the growing season and monitoring will be carried out three times yearly.

The following examples represent qualitative or low-intensity quantitative monitoring conducted primarily to track the overall success of our protection efforts in Wisconsin. On Schluckebier Sand Prairie because of the rarity of Lespedeza leptostachya we are able to count the number of clones, the number of individuals per clone, and record heights. Similarly, the number of stems of Cypripedium candidum occurring on both Summerton Bog and Snapper Prairie where there are active prescribed burning programs, can be accurately counted each year. The number of individuals of glass lizard, box turtle, and 5 lined-race-runner are counted every year at Spring Green. Visual changes in wet prairie, fen, oak-opening, wet-mesic prairie, dry-mesic prairie, and sedge meadow all in Chiwaukee Prairie, Wisconsin, are recorded through annual photographs taken from permanent photo points. In some other states, aerial census has been used effectively. Sandhill cranes are censused from the air at Mormon Island, Nebraska, and bald eagle nests are similarly censused in Maine on nine island preserves. On Schwamberger Preserve in Ohio, 16 plant species are monitored yearly using the field survey forms. These are just a few of the low-intensity monitoring programs representing a yearly census of the species and communities protected on Conservancy preserves.

The Conservancy does not have the resources needed to monitor all of the over 3,000 populations and stands of endangered species and communities protected on its preserves. To address the questions of when, how, and which elements will be monitored, the Conservancy applies the principle of triage, a system used to allocate a scarce commodity, in this case conservation resources, only to those capable of deriving the greatest benefit from it. Elements to be monitored should be high ranked (endangered and threatened) and have a demonstrated need for monitoring such as being highly threatened, seral, or occurring in a seral community. Monitoring should also be carried out when active management is needed but responses to different management practices are unknown. Inviable or indefensible populations or stands should not be allowed to drain limited conservation resources.

Monitoring methodology should be tailored to the nature of the element and the overall reason for monitoring. Monitoring methodology can be as simple as a yearly recording of presence or absence or as intensive as needed to establish and document a management research program or provide statistically reproducible data to protect The Nature Conservancy's legal interests.

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Section 3. Management Problems

PANEL ON FIRE MANAGEMENT IN RESEARCH NATURAL AREAS: SUMMARY COMMENTS

Bruce M. Kilgore

Determining the appropriate role for fire in any given research natural area (RNA) requires two things:

1. Knowledge about the ecological conditions and processes involved in the RNA
2. Clearly stated management objectives

While we would normally expect to maintain natural conditions in an RNA by allowing natural processes to occur, this is not always possible in the real world. This is especially true where natural fire is concerned because RNA's tend to be small and often are surrounded by commercial resource lands. Hence, deliberate manipulation is usually required to maintain a semblance of "natural" conditions, either by using scheduled prescribed fires or by suppressing natural fires. Such manipulation is always aimed at maintaining the unique vegetation type or feature the RNA has established to protect or perpetuate. This prompts me to comment briefly on terminology.

Too often the point seems overlooked that suppressing fires is manipulation just as surely as use of human-ignited prescribed fire (scheduled ignitions) is manipulation. Both have their place in management strategies, but both are unnatural. So to adhere to strict natural area management concepts, we would have to literally do nothing. Even then, unless natural lightning ignitions from outside our small RNA's (or wilderness or parks) are allowed to burn into these areas (as they have done historically), we would have a human-modified system. Thus the best we can do is to simulate natural conditions in RNA's and in other natural areas.

A second terminology problem involves the word "preservation" when this word is applied to dynamic vegetative ecosystems. We cannot (and would not want to) keep such ecosystems static. Instead we want to perpetuate their natural, dynamic condition. So I would propose the term "perpetuate" or "perpetuation" rather than "preserve" or "preservation" to describe our objective in using fire in RNA's and in other dynamic natural systems.

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It would appear that the Forest Service feels there is a quandry about whether our primary emphasis in managing RNA's should focus on perpetuating (or maintaining) vegetative structure and composition or perpetuating natural processes. The National Park Service seems to focus primarily on natural processes. The Nature Conservancy uses prescribed burning when and where it contributes to the goal of maintaining species and communities targeted for preservation (or perpetuation).

Ideally we would perpetuate both natural conditions and natural processes (Kilgore 1984). Chuck Wellner's (1984) concerns at the Wilderness Fire Symposium about the impacts of fire on undisturbed and climax stage vegetation in RNA's would support the need for careful focus on the objectives for which individual Research Natural Areas were established. Where the primary emphasis is on remnant stands of old-growth forests or sensitive rare, endangered, or threatened plant species (which would be damaged by fire), then a policy of fire exclusion would take precedence in order to preserve specific vegetation conditions or structural features. (Even here, this is a short-term view because most ancient stands were visited or even recycled by fire at intervals of 100 years or more.) On the other hand, in the majority of RNA's in the Inland West that were established to perpetuate a seral stage of succession or species that require such a stage for survival, prescribed fire may be needed to simulate the natural fire process.

This is particularly true where after a long period of fire exclusion, it may be essential to reduce litter or down woody fuel accumulations by carefully controlled prescribed burns. Because of the small size of most RNA's and the differences in management philosophy (in most cases) between the RNA and the neighboring landowners, allowing natural (lightning) fires to burn is usually not practical, even in those cases where the results of all natural processes are in keeping with the RNA objective. Here, it may be the best management strategy to simulate natural processes through use of prescribed burning, selecting as closely as possible a nearly "natural" season, frequency, intensity, and size of burn. Practical logistics and economics tend to nearly preclude any other approach to use of fire in RNA's.

We are dealing with some difficult philosophical and policy matters when we suggest use of prescribed fire in natural areas. Janet Johnson (1984) pointed out the paradoxes involved in a program that (1) has a goal of perpetuating systems that must change (short run) to stay the same (long run), and (2) in which our efforts to manage for perpetuation introduces human influences into natural systems although the purpose is to correct earlier human influences. Yet, human influences (fire suppression and others) have strongly impacted RNA ecosystems for more than 50 years. With large numbers of Americans showing strong interest in our public lands, we must manage all lands for whatever goals are decided upon. We cannot simply leave things alone and expect that will take care of RNA management.

It has been pointed out that trying to maintain dynamic biological complexes in any fixed condition is both futile and artificial (Johnson 1984). With the exceptions noted for RNA's established specifically to preserve examples of undisturbed and climax stage vegetation, the current trend in vegetation management would seem to be to try to allow natural processes to operate (or to simulate such processes), recognizing this is more likely to produce natural conditions than attempting the difficult task of holding dynamic processes static to maintain certain structural vegetative conditions.

In summary, then:

1. We need to be flexible in our plans for use of fire in RNA's. Depending upon whether we want to perpetuate a dynamic ecosystem through natural processes or whether we want to preserve existing "climax type" vegetation conditions, we may simulate natural fire processes through use of prescribed fires or we may attempt to suppress most fires with the least impact methods possible (the latter would be the exception in most ecosystems of the Intermountain West where fire--at shorter or longer intervals--is the rule.
2. Our overall task is to preserve (or perpetuate) both natural conditions and natural processes.
3. The specific goal is to maintain the ecological conditions for which each area was designated in as near natural a state as possible.
4. If fires ignited by lightning or Indians in lower elevations or vegetation types outside RNA's played a major role in igniting fires within the RNA, we need to consider use of prescribed fires to simulate such outside ignition sources.
5. We need to think through the role of fire and fire use at the time RNA's are being established. The location of the RNA may affect our ability to manage fire in the way most desirable.
6. More information is needed on specific fire history--the natural season, frequency, and intensity of fires in RNA's--to allow prescribed fires to better simulate the natural role of fire.
7. Concise planning documents are essential for each RNA to define how, when, why, and under what specific prescription fire will be used in the RNA. In developing the plan, give high priority to fire weather forecasts, burning indices, and fire history and vegetation patterns from the past.
8. Developing skilled prescribed burning personnel is an essential component to effective fire management programs in RNA's where use of RX fire is appropriate.
9. A reliable system for storing and retrieving fire treatment and effects information is a highly desirable addition to the fire management program of all RNA's.

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FIRE IN RESEARCH NATURAL AREAS IN THE FOREST SERVICE

James E. Lotan

ABSTRACT

Research natural areas (RNA) in the USDA Forest Service are established to preserve a representative array of all significant natural ecosystems and their inherent processes. They are to be used to obtain information about natural system components, inherent processes, and comparisons with representative manipulated systems. Flexibility in protection and management is permitted to meet local situations, but manipulative practices are generally not used. The quandry is whether to strive for preserving natural vegetative conditions or to permit natural processes to function. Inasmuch as the role of fire varies in RNA's, flexibility is permitted. Management practices should be documented in the establishment report or in a management plan following establishment.

FOREST SERVICE RESEARCH NATURAL AREAS

Forest Service policy is similar to that stated by the Federal Committee on Ecological Reserves (1977). Forest Service RNA's are considered as part of the National System described by the committee. Two purposes for developing this system are:

1. To preserve a representative array of all significant natural ecosystems and their inherent processes as baseline areas . . .
2. To obtain . . . information about natural system components, inherent processes, and comparisons with . . . manipulative systems.

The National System in 1977 included almost 400 separate RNAs and covered over 4 million acres in 46 States. The Forest Service's contribution to this system includes 148 different RNA's covering nearly 178,000 acres (≅70 000 ha). They average 1,164 acres (≅470 ha).

FOREST SERVICE POLICY

The Forest Service Manual (FSM 4063) states that RNA's are limited to research, study, observations, monitoring, and educational activities that are nondestructive and nonmanipulative. Generally, it is Forest Service policy that RNA's be protected against activities that modify ecological processes. Logging and grazing is limited except for where their use is essential for maintenance of a specific vegetative type. Apparently, policy was written providing for flexibility depending upon the local situation.

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Protection.--There is flexibility (ambiguity?) in policy regarding protection. The policy is that for each RNA there be specific management direction for protection from fire, insects, and disease. Yet in the very next sentence, "Maintenance of the natural processes within each area will be the prime consideration."

Fires within the area will be allowed to burn undisturbed unless they threaten persons or property outside the area, or the uniqueness of the RNA. Debris resulting from fires should not be cleaned up nor should any fire hazard reduction or reforestation be undertaken.

Vegetation Management.--Management practices are permitted that are necessary to preserve the vegetation for which the RNA was established. Practices such as grazing, control of animals, and prescribed burning are permitted with the proviso that only proven techniques be used. The intent is that the management practice must more closely preserve the vegetation and processes than would no management.

The underlying emphasis in RNA management is on preserving and protecting features of each area by controlling any disruptive use, encroachment, and development. Activities such as logging, grazing, burning, or restocking are prohibited unless the activity replaces natural processes and contributes to the protection and preservation of the designated feature. Such a practice is invoked only after thorough research and testing indicate that it adequately or favorably benefits the feature. In such an instance, a portion of the tract is left untreated as a control to justify the practice. Current policy clearly permits flexibility and interpretation.

THE PROBLEM

The problem of handling fire in research natural areas was recently discussed at the Wilderness Fire Symposium held in Missoula, November 15-18, 1983. Johnson (1984) and Wellner (1984) both did an excellent job of discussing the issues. Basically, we have the task of preserving both natural conditions and processes. Forest Service policy permits judgment regarding these goals. As Johnson (1984) stated: "These goals may not always be mutually compatible."

Fire is considered a natural process, but fire may also eliminate the very uniqueness for which the RNA was established.

Bonnicksen and Stone (1982) distinguished between these two goals and pointed out the inherent contradiction. Structural maintenance objectives are designed to maintain the structure and composition of vegetative communities. Process maintenance objectives preserve natural processes and accepting whatever structure and composition in the vegetative community that results in these processes.

Wellner's (1984) concerns are that most RNA's are established to preserve a condition (structural maintenance objective) and that undisturbed, advance stages of ecological development are becoming more rare. He cautions that fire be used only where essential to maintain conditions the RNA was established to protect.

RNA ecosystems vary from seral to advance stages of succession, and most certainly, no one overall fire management practice should prevail. There should be an equally vast array of fire treatments to meet the varied requirements of research natural areas. Where might natural, prescribed fires be used? What levels of protection are required? I believe that we must approach this subject with care, keeping in mind the role fire has historically played in each area and the purpose or particular feature of the area set aside.

A COURSE OF ACTION

The overall goal of RNA management should be to maintain the ecological conditions for which the area was designated in as near natural state as possible. The natural role of fire varies considerably in the vast array of ecosystems in the RNA system. Each area should be evaluated for the role of fire and fire hazard. Specific fire management objectives need to be established for both protection and use of fire. Ideally, this should be done at time of establishment and included in the establishment report. For those areas where the original establishment report did not address these issues there should be an additional management plan developed to include fire management concerns.

Fire is a powerful process and may be either harmful or beneficial. Fire management is the deliberate response to and use of fire based on sound plans that contain prescriptions to meet land management objectives for an area of interest (Fischer in preparation). These prescriptions need to be determined to meet the objectives of RNA's.

Current Forest Service policy is being rewritten. My comments here have been made regarding Forest Service Manual statements as they now stand.

Flexibility and judgment are now permitted and should be retained. The revision should retain this flexibility and permit professional judgment. I would like to see more direction to address fire problems more in keeping with recent changes in fire management policies. And to address the quandry of whether the RNA has been established to maintain structure and composition or processes. Fire is a powerful force and must be addressed.

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FIRE AS A MANAGEMENT TOOL OF THE NATURE CONSERVANCY

Allen A. Steuter

INTRODUCTION

In 1962 Donald B. Lawrence and Frank D. Irving conducted a prescribed burn on the Helen Allison Savanna in Minnesota. This was the first prescribed burn on land owned by The Nature Conservancy and our interest in fire as a management tool has been developing since. At the present The Nature Conservancy owns approximately 700 preserves encompassing over 600,000 acres nationwide. In the Midwest Region alone there are 200 preserves with grassland or savanna communities in need of fire management. These preserves range in size from one acre to 54,000 acres and are often surrounded by intensively managed agricultural land. Many of the native plant communities and species of the Midwest Region are known to have developed under a relatively high historical fire frequency and require this disturbance to maintain vigor. Only the few largest preserves have permanent on-site staff. In this setting it becomes apparent that more than a superficial interest in prescribed burning is needed for efficient natural area management.

CURRENT DIRECTION

The policy of The Nature Conservancy is to use fire management when and where it contributes to the goal of maintaining species and communities targeted for preservation. Fire management actions are designed to maintain a high level of personal safety and contain the fire to predetermined areas for which specific management objectives have been established. Fire management represents a major allocation of time and physical resources. Consequently, the fire management effort is scaled to the endangerment of fire dependent species/communities, and to the urgency of instituting a fire program on a particular site.

Fire management on Conservancy preserves is focussed on prescribed burns resulting from intentional ignition. Because most preserves are small, unstaffed, and/or bordered by agricultural land, a policy of "let burn" within prescribed conditions for unintentional ignitions is not realistic. Specific objectives to be accomplished on a given site also require more managerial control than can be obtained by prescribed fire from unintentional ignition.

MANAGEMENT IMPLICATIONS

The Conservancy's fire management program relies on stewardship personnel taking an "active" role in assessing the ecological need for prescribed burning, allocating resources to meet these needs, and conducting the burn under prescribed conditions. An organizational commitment expressed in the form of policy/guidelines, training, planning coordination, and equipment is required before land stewards feel comfortable taking a prescribed burn out of the office and into the field. A key role is played by program administrators in encouraging and facilitating the safe and effective use of fire.

At present, fire management in the Conservancy is evolving toward a system of concise planning documents developed for each preserve by the person directly responsible for management. These plans are reviewed and must receive approval by regional stewardship staff who may call on outside expertise as needed. Fire safety is paramount. However, a premium is placed on eliminating unnecessary duplication of effort if the required information exists in other preserve planning documents. The objective is to have a concise treatment of: (1) justification - why fire is needed and relative priority for maintaining target species; (2) site fire plan - rationale for timing and frequency of fire treatments; (3) prescribed burning plan - specific range of conditions under which the fire will be safe and effective; (4) fire summary report - a record of treatments, and notes on problems and recommendations; (5) fire effects documentation plan - priority and level of fire effects monitoring; and (6) fire effects report - species/community response information. The long-term effectiveness of this system relies on adequate review of planning documents, fire effects information from built-in monitoring and other technical research, and trained people to conduct the prescribed burning.

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RECOMMENDATIONS

There is a need to increase the number of skilled prescribed burning personnel. Workshops are an important component of a training program. However, several years of actual management burn experience seem to be critical for producing the confidence necessary in on-site prescribed burn leadership. Developing this leadership corps of prescribed burning personnel appears to be the bottle-neck of many training programs. Stewardship personnel should be strongly encouraged to participate in scheduled burns, and fire leaders should make the most of management burns as educational opportunities for grooming additional burn leaders.

The technology and philosophies of the fire control industry should not be transferred to a prescribed burning program without a critical evaluation of their efficacy. The objectives and circumstances of most prescribed burns are radically different from wildfire situations. An efficient prescribed burning program will not be equivalent to an efficient fire control program.

A reliable system for storing and retrieving fire treatment and effects information will provide the necessary feedback for an increasingly effective prescribed burning program.

RESEARCH NATURAL AREAS AND FIRE IN THE NATIONAL PARK SYSTEM

James K. Agee

The research natural area concept is consistent with resources management policies of the National Park System. Research natural areas (RNA's) are tracts where "natural processes are allowed to dominate" (Franklin 1970) and where research and education are encouraged. Processes rather than objects are the focus of presentation efforts.

Current National Park Service management policies recognize fire as an important ecosystem process and one that, if feasible, should be allowed to play its natural role in ecosystems. Fire plans within national parks commonly use a combination of fire suppression and prescribed natural fire to meet resources management objectives. Prescribed fire is also used in situations where ecosystem restoration by fire is desirable or where the use of natural fires is not feasible, such as around developments, along boundaries.

The same types of policies are applicable in RNA's (Federal Committee on Ecological Reserves 1977): "Catastrophic natural events . . .{such as fire} . . . should ideally be allowed to take their course . . .", and prescribed fire is mentioned as a possible restorative tool.

In both national parks and RNA's, fire suppression is sometimes necessary. Human-caused wildfires will be suppressed in RNA's as elsewhere in parks. Low-impact methods of suppression are preferred, with the decision on use of strategy based on the overall least ecological impact to the RNA. If prescribed natural fires need suppression, firelines and retardants will be applied outside RNA's to the extent possible.

The general compatibility of purpose between RNA's and national parks suggests that few problems should arise as RNA's are nestled in parks. Such general compatibility should not imply that fire management problems do not exist; these problems can be summarized in several categories.

LOCATION AND SIZE

Although size is not a problem for RNA's in parks, location is very important. Many RNA's have been located near park boundaries or roads that provide good access but usually results in the RNA being in a fire exclusion buffer zone.

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COMPATIBILITY WITH RESEARCH OBJECTIVES

Although research is one objective of RNA's, not all research may be designed to include periodic disturbance by fire in the midst of a project. This is a bigger problem for short-term than long-term research. If prescribed fire is used, its "naturalness" may also be debated by researchers.

PRESCRIBED BURNING

Prescribed fire is allowed in all land-use categories in the National Park System, including RNA's. Mimicking the natural role of fire by planned ignitions, however, is a judgment call. Poor information bases make it difficult to know if burning is in the proper season and represents both the mean and variance of historical frequencies and intensities.

ABORIGINAL BURNING

In RNA's where the fire regime included frequent, low-intensity fire, Indian burning was often part of the available record. Should this be considered natural?

CONCLUSION

Research natural areas should be allowed to experience natural disturbances, including fire. Suppression actions should avoid RNA's whenever possible. Researchers should recognize the potential of fire in both planned facilities and design so as to avoid the need for enclaves within enclaves. In the placement of RNA's, the ability to manage fire should be one criterion in the establishment process.

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PANEL ON GRAZING MANAGEMENT IN RESEARCH NATURAL AREAS: SUMMARY COMMENTS

Walter F. Mueggler

ABSTRACT: Grazing management on research natural areas (RNA's) is briefly discussed, including early objectives, current status, and future recommendations.

HISTORICAL PERSPECTIVE

Federal land management agencies have been concerned with the establishment of a research natural area (RNA) system within the United States for over 50 years. The present thrust, however, appears to date from about 1966 with the formation of a multi-agency Federal Committee on Research Natural Areas. In 1968 this committee in its directory of RNA's on Federal lands clarified desired objectives of the program and provided guidelines on use of the areas. Among the objectives were the preservation of examples of all significant natural ecosystems for comparison with those influenced by people, and preservation of gene pools for typical, rare, and endangered plants and animals. Management guides generally directed that natural processes be allowed to provide for continuance of the selected ecosystems.

In practice, emphasis has been placed on identifying suitable areas and officially establishing them within the RNA system. Once an area was within the system, lines were drawn and management directed toward "protection" from human influences. Little thought was given to the natural processes and dynamics of specific ecosystems or to the positive role of seemingly destructive agents, especially fire and grazing, in the maintenance of certain systems. As a consequence, management of RNA's typically became synonymous with protection rather than being a conscious attempt to recognize and provide for the continuance of those essential processes.

CURRENT APPROACH

The panelists at this symposium briefly reviewed the approach of The Nature Conservancy, the Forest Service, and the Fish and Wildlife Service toward grazing management in RNA's. There appears to be general concurrence regarding two major considerations related to grazing. First, candidate RNA's representing grassland ecosystems that have not had at least some livestock use are virtually nonexistent; thus, ecosystem representation must depend upon selections from those areas "least" altered by livestock grazing. Such decisions on relative alteration are highly subjective but necessary if we are to proceed with expanding grassland representation within the RNA system. Second, natural processes involved in the formation and maintenance of perhaps the majority of grassland ecosystems, particularly in the plains, included grazing by large native herbivores. Duplicating or mimicking this natural process may be essential to the preservation of such ecosystems.

The Nature Conservancy currently appears to be at the forefront in evaluating, planning, and implementing the type of direct management needed to maintain specific grassland ecosystems. Theirs is truly an aggressive approach to RNA management. Federal agencies are becoming increasingly sensitive to the need for active management, including purposeful grazing, to preserve examples of certain ecosystems; however, the lack of funds dedicated to the Federal RNA program have seriously constrained the intensive management that may be required to maintain such areas.

FUTURE DIRECTION

The thrust of the Federal RNA program has been to select and establish representative RNA's. This effort must continue if we are to achieve the goals of adequate ecosystem representation. However, the problems associated with RNA management must now be seriously addressed, especially by Federal agencies, or the integrity of the RNA program may be jeopardized.

Effective management consists of several important components. The uniqueness of each RNA must be recognized and, for each, specific management objectives established. A careful assessment of the natural processes controlling the welfare of each ecosystem is required (such as the role of fire or grazing by native herbivores). A management plan must be creatively formulated and implemented to permit these natural processes to continue, as well as to mimic essential processes no longer extant. An adequate system of monitoring is required to determine if the management objectives for a given area are being met and whether adjustments to the management plan are required.

Such active management of Federally administered RNA's does not appear possible under current funding levels. Secure, dedicated funding at a level commensurate with projected long-term RNA values will be required to permit the level of management needed to maintain the viability of the RNA system. Simply drawing a line around an area is not enough.

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GRAZING MANAGEMENT IN RESEARCH NATURAL AREAS

IN THE NORTHERN REGION OF THE FOREST SERVICE

Wendel J. Hann

ABSTRACT: This paper summarizes the policy of the Northern Region of the Forest Service relating to evaluation and management of grazing by big game and domestic livestock on research natural areas (RNA). Where livestock and/or wildlife grazing is a significant impact on a candidate or established RNA, an evaluation should be made concerning historical grazing impacts. RNA's should be selected that closely represent natural situations and managed to maintain those conditions. Livestock may be used for vegetation management to maintain the plant community as a natural type if the technique has been tested and will produce the predicted results.

INTRODUCTION

Policy concerning selection, establishment, and management of RNA's is outlined in the Forest Service Manual. The objective of the RNA program is to protect areas that typify natural situations relatively undisturbed by human activities. One of the primary disturbances is that associated with grazing of domestic livestock. Livestock grazing can cause significant changes in plant communities when compared to the natural situation. Human influence in displacing wildlife from their native habitats and concentrating their use in areas that did not naturally support heavy use has been an additional impact.

FOREST SERVICE POLICY CONCERNING GRAZING IN RESEARCH NATURAL AREAS

The basic philosophy for RNA establishment and management is to "promote and protect natural diversity in all of its forms." This is done by establishing and protecting areas that typify important and unique conditions of forest, shrubland, grassland, alpine, aquatic, geologic types, or other natural situations. Policy is specific in stating that RNA's are for nonmanipulative research, observation, and study. When selecting and establishing RNA's, a basic guideline is that the area should not show evidence of human disturbance for at least the past 50 years. However, if for a given situation there are no sites that meet this criterion, then the least disturbed area may be selected. Candidate RNAs should be evaluated relative to impacts from grazing by both wildlife and domestic livestock based on the following criteria:

1. Historical use by native herbivores should be documented. Both the recent history of use since modern settlement and the history of plant species development and herbivore use through geologic time should be considered.
2. The present conditions should be compared to what is thought to have been present prior to the influence of modern settlers.
3. Availability of areas representative of different ecosystems should be considered. If few representative areas are available, then an area that is somewhat disturbed may have to be accepted.

Management decisions related to RNA's may present a more difficult problem than that of selection and establishment. Forest Service policy is to protect "against activities which directly or indirectly modify ecological processes if the area is to be of value" and further restricts livestock grazing "to those areas where their use is essential for the maintenance of a specific vegetative type." The grazing system that is used should be proven such that its use will provide a closer approximation to the natural situation than without grazing.

SUMMARY

Grazing is a natural process in many of the plant communities in the Northern Region. The major ecosystems for which grazing should be considered part of the natural process are the shrub- and grass-steppe. However, grazing has also been an important part of the development of open forests, savannah forest-steppe, subalpine and alpine openings, and wetland shrub and herbaceous types. Forest Service policy allows for use of livestock to manipulate natural vegetation if a tested management system can be implemented to produce plant communities similar to those that would exist naturally.

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NATURAL AREA MANAGEMENT

OF MONTANA NATIONAL WILDLIFE REFUGES

Barnet W. Schranck

INTRODUCTION

Research natural areas are of special interest not only to scientists but to a wide variety of people concerned with the welfare of various ecosystems. The purpose of this paper is twofold: first, to discuss the management of officially designated research natural areas (RNA) on national wildlife refuges (NWR) in Montana; secondly, to provide a broad overview of grazing management on NWR's, with special reference to the Charles M. Russell (CMR) NWR.

RESEARCH NATURAL AREA

The U.S. Fish and Wildlife Service, along with other agencies, is committed to the RNA program as initially developed in 1966 with the Federal Committee on Ecological Reserves. As a result of the thrust to set natural areas aside, 174 RNA's on 82 NWR's involving 1,228,101 acres were established nationally. In Montana, the Service is responsible for 10 RNA's: CMR - 4, Benton Lake NWR - 1, Medicine Lake NWR - 4, and Red Rock Lakes NWR - 1. Approximately 1,457 acres are involved, and the areas vary in size from 15 to 392 acres. Seven of the 10 areas are islands. According to the 1977 Directory of RNA's on Federal land, 30 areas covering 71,580 acres located in Montana are managed by a variety of Federal agencies. The Service is responsible for only 2 percent of the acreage.

Since the establishment of these areas, no grazing, haying or burning has been done; nor do we anticipate any in the near future. Also, there has been no specific use of the RNA's by the scientific community.

The Service does have guidelines on the management of RNA's. Generally, an area is allowed to advance toward a climax. However, vegetation may be maintained at a desired seral stage when the primary purpose of the area is dependent on a specific stage. Grazing, haying, and burning may be done only with the development of an approved plan.

NWR SYSTEM AND LAND MANAGEMENT

One of the goals of the Service is "to preserve a natural diversity and abundance of fauna and flora on refuge lands." This is certainly in accordance with the objectives of the Federal Committee on Ecological Resources, originally dealing with RNA's. Grazing, haying, and burning of vegetation are considered tools to manipulate habitat for the benefit of wildlife. It is important to remember that NWR's are not multipurpose areas. They are set aside for wildlife use, and other uses are secondary. Management actions are governed by the NWRS Administrative Act of 1966, which basically states that all activities must be compatible with the purpose for which the land was acquired.

CMR GRAZING PROGRAM

The development of the CMR land management program presents an interesting story. Executive Order (E.O.) 7509 created the Fort Peck Game Range in 1937 and, since 1976, it has been known as the Charles M. Russell National Wildlife Refuge. Initially, the area was jointly managed by the Bureau of Land Management (BLM) and Fish and Wildlife Service for 40 years under the Taylor Grazing Act. Court action in 1975 stated that BLM was not giving adequate consideration to wildlife and required an environmental impact statement (EIS) for developing a master plan. Various types of litigation followed, but on October 13, 1983, the U.S. Ninth Circuit Court of Appeals ruled that: (1) wildlife has priority in access to forage in accordance with E.O. 7509; (2) beyond those limits, wildlife and livestock have equal priority; and (3) CMR is to be administered under the NWR's Administrative Act of 1966. The draft EIS will be available for public review in 1984.

The Refuge Mission is ". . .to preserve, restore, and manage in a generally natural setting a portion of the nationally significant Missouri River breaks. . . optimize wildlife resources and compatible human benefits. . ." This, too, is in line with the concept of RNA's.

The planning process used to enable the Service to meet this mission consisted of four steps. The first step involved the completion of range site and condition surveys to determine available animal use months (AUM's). This was done in 1978 using the Soil Conservation Service's (SCS) National Range Handbook. Step two involved the development of a slope/water matrix based on livestock observations in relation to slope and distance to water. For example, AUM's associated with 0-10 percent slopes and 0-0.25 mile from water were assigned to livestock. AUM's associated with 50 percent and greater slopes were assigned to wildlife. AUM's beyond 0.5 mile on steep land and 2.5 miles on level land were also assigned to wildlife. Step three took in consideration erosion potentials, and livestock AUM's were reduced accordingly. The fourth step involved the evaluation of various sites as to the

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documented wildlife value. AUM's were assigned to wildlife in these cases.

It should be pointed out that this procedure was used for development of the proposed action in the DEIS, and as such, it is not final. A record of decision on the management of CMR will probably be issued late this year. In addition, a number of items are still under litigation, which must limit my comments.

In any event, once the broad management plan is in place, specific management plans covering the 67 allotments will be developed in cooperation with the 92 permittees and landowners.

The grazing program will be monitored and adjusted as needed, using information obtained from (1) permanent photographic sites, (2) Daubenmire transects, (3) Robel transects, and (4) exclosures.

SUMMARY

Research natural areas managed by the Service in Montana are basically unchanged since their establishment, and none are currently grazed. Grazing at CMR is currently being addressed in a draft EIS, and based on the court decision, management will be directed toward wildlife. This will result in a more natural ecosystem.

GRAZING MANAGEMENT IN THE NATURE CONSERVANCY

Mark Heitlinger and Allen A. Steuter

INTRODUCTION

The goal of The Nature Conservancy is to preserve natural diversity through securing habitat for the most endangered species and maintaining representative examples of natural communities. In most grasslands large hooved animals were an important evolutionary and ecological force for millions of years. Grazing modifies vegetation height and density. This strongly affects habitat quality. Differential responses to grazing are observed in birds, mammals, insects, and microbial activity. Diet selection by herbivores influences vegetation composition since plant species decrease, increase, or invade with grazing. Different grazing species vary in their forage preferences and other aspects of grazing behavior. To plants, critical factors are the severity, frequency, and seasonality of defoliation. Management can modify innate grazing tendencies through regulating stocking density, fencing and herding, burning, placement of minerals and water, and other means. One-herd multipasture systems provide the most control over grazer-plant interactions. Many authorities believe the type of discontinuous forage removal provided by rotational grazing mirrors what occurred before European culture and domesticated animals invaded rangelands. In large wilderness areas, native ungulates may function much as they did prior to white settlement. Even in these situations it is difficult to provide unrestricted opportunities for migration and predator-prey interactions. Grazing on relatively small Nature Conservancy preserves cannot be justified on the grounds of establishing a complete grassland ecosystem. We use grazing as a tool to mold admittedly incomplete systems toward a structure that we infer to be similar to that of aboriginal times. Grazing is a tool to create preferred habitat for high priority species. Grazing may also be used when we are forced by constraints to utilize less than optimal management treatments. For example, high stocking density, short duration grazing may substitute for fire where burning is not feasible. Certain grazing systems aid in the recovery of abused grasslands.

CURRENT DIRECTIONS

Current directions may be summarized by two examples. At Cross Ranch (ND) we have plans to establish a 1,000-acre bison pasture in which fire is used to induce rotational grazing. We believe herds of native bison in this region grazed some areas severely in a deferred or rest rotation cycle. There was probably also chronic light grazing by solitary animals and small local herds. This inferred grazing regime is to be simulated by burning four 20-acre areas each year on a 10-year fire rotation. We expect the bison to graze heavily on the freshly burned areas and lightly to moderately on the rest of the pasture. Because burning is rotated, heavy grazing should last only about 1 or 2 years every 10 years. Approximately 20 percent of the pasture will be permanently unburned and open to grazing. Cattle grazing and fire-only management elsewhere on the preserve also provide comparison areas.

At the S.H. Ordway Prairie (SD) we have established several different fire, grazing, and combination treatments. Objectives include reducing the exotic Kentucky bluegrass, producing pasture-to-pasture variation in vegetation structure, and studying the role of perturbation in the northern mixed prairie. In part of the preserve cattle graze for three 6-week periods in each of three pastures. The grazing period is rotated so a pasture is grazed during each grazing period only once in 3 years. In another three pastures the system is duplicated except that the period of grazing is not rotated. Other comparisons are provided by continuous cattle and continuous bison grazing during the same 18-week period, dormant season bison grazing, and fire-only management including several different fire frequencies. The season-long grazed pastures and one of the deferred rotation pastures are burned once in 3 years.

IMPLICATIONS

Grazing animals, even if native species, do not insure duplication of the selectivity, severity, frequency, and seasonality of defoliation as it occurred in aboriginal times. There are special problems with grazing including uneven distribution, edge effects along fences, and weed seed dispersal. Grazing prescriptions must be clearly defined and enforced. Herds of appropriate size, kind, and class of animal must be located. Grazing may be interpreted by some as a violation of corporate farming laws and a disqualification for property tax exemption. Animal control is parti-

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cularly difficult on small, unstaffed preserves. The desired background information is often lacking and grazing effects are difficult to study.

RECOMMENDATIONS

Despite these problems, The Nature Conservancy uses grazing to achieve grassland preserve goals. The process involves making informed inferences about the native grazing regime; carefully defining preserve objectives and relating them to forage removal; considering constraints; planning the grazing units, schedules, species, and stocking limitations; developing fences and other facilities as needed; administering arrangements and monitoring compliance; conducting ecological monitoring and evaluation. We recommend using native grazing species when possible, including fire in the treatment plan, and maintaining reference areas for comparative purposes.

Monitoring should be used to assess achievement of preserve goals. It is unreasonable, however, to defer management until the grazing effects are understood in minute detail. We must have a degree of faith in our ability to infer ecosystem structure and function and to use monitoring as an early warning system to detect serious problems.

Numerous grazing systems have been described. There is a temptation to begin the planning process by selecting from this menu of tools. It is preferable to begin by identifying the ecological objectives to which grazing may contribute and customizing the tool to do the job.

Section 4. Symposium Conclusions and Poster Session Abstracts

BASELINE MONITORING AND MANAGEMENT OF RNA'S:

SYMPOSIUM CONCLUSIONS

Richard G. Krebill, Janet L. Johnson, and Robert D. Pfister

Since the start of the research natural area (RNA) concept in the 1920's, proponents have placed prime emphasis on initial establishment of areas to provide an extensive network of undisturbed sites for future research and education. Progress has been substantial with some 440 areas now activated, and perhaps an equal number under consideration for establishment within the next decade. Generalized policies for management of research natural areas have developed; but in practice our management often neglects such factors as the natural role of fire and of ungulate grazing. We have done surprisingly little to develop baseline information useful to determining stability of inherent ecosystems. With concerns for these subjects in mind, this symposium was formulated to discuss and provide new insight into baseline monitoring, fire management, and grazing management for research natural areas.

The opening keynote comments of Jerry Franklin chastised the scientific community for our poor record of scientific use and documentation of activities on research natural areas. He pointed to the danger of "use it or lose it," and offered some helpful suggestions to increase the scientific viability of research natural areas. Jerry concluded his comments with the hope that this symposium would ". . . help stimulate baseline monitoring and research in the outstanding system of natural areas that we are creating. . . ."

Baseline monitoring was viewed in this symposium as an important activity to document changes that might otherwise be overlooked. Effects of climatic shifts on ecological succession might be detected. Monitoring can provide early alerts to environmental impacts such as toxic air pollutants. Quantifying the status of natural ecosystems serves as baseline information needed to compare changes on manipulated sites of similar ecosystems. In this way, research natural areas are somewhat akin to range management's grazing exclosures, except that because of their larger size and management, they need not suffer confounding edge effects.

Although monitoring is important, several participants pointed out that research natural areas also have a large and growing utility for future research as the presence of undisturbed areas becomes a rare part of the nation's lands. A case in point involves the northern Idaho forest habitat type revision study, which depended on plot locations within mature, undisturbed stands. The search for suitable sites was minimized by going directly to proposed and established RNA's in northern Idaho. With time, research on RNA's will benefit from the synergistic effects of focusing a myriad of studies on special sites.

There are many components of the ecosystem worthy of monitoring. Our interest might be with the cryptogams, whereas others are concerned with vascular plants, animals, aquatic microorganisms, or the soil, water, and air resources. Still others are more interested in processes rather than components of ecosystems. But monitoring is expensive and time consuming, so how might it best be done? Symposium participants provided the following advice: First, for each research natural area, thoughtfully define objectives. Next, identify what is to be regularly monitored giving priority to the utility of achieving objectives. (Other interests should be encouraged to perform studies in research natural areas as their findings may in fact become bases to our unpredicted future.) Sampling designs should be simple and repeatable by others and over long periods of time. Randomization and replication are paramount attributes of any valid statistical design. Proper planning of monitoring activities cannot be overstressed, and consultation with a statistician is highly recommended. Statisticians may advise use of progressive approaches of data analysis such as the "cumulative sum" method, as well as the standard techniques. Consider the possibility of coordinating an interdisciplinary team to sample various components and processes within any RNA. When performing field studies, be sure data collectors are well trained and periodically check for conformance to standards. Archive the data so that it is secure and readily available to yourself and to others for perpetuity. Publications are time-proven in that respect, and the computer age offers attractive possibilities. Be cost-effective, as the monitoring job is immense, and resources to physically tackle the job are small.

Our attention also turned productively toward the role and management of fire and grazing on research natural areas. Again, symposium participants stressed the need for declaring objectives on a site-specific basis. Natural disturbances such as fires and grazing by native ungulates have had a major role in shaping the structure and composition of most ecosystems represented within

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research natural areas. If these areas are to remain "natural," shouldn't fire and grazing be retained? We agreed, for the most part, that our policies and their implementation must be flexible. The relative small size of research natural areas often necessitates active management through reintroduction of ecological processes to stimulate natural conditions. For areas where the objective is to maintain old-growth forests, it may be appropriate to exclude fire for centuries. But where we're trying to maintain grasslands, we may need to prescribe annual fires and encourage grazing to assure an appropriate vegetative composition. Native ungulates might be favored for grazing, but some participants suggest that domestic livestock grazing could be used as a practical alternative if applied under good management. The thought that fire and grazing might best be used in concert on some sites, though logical, was an important new thought to the symposium organizers.

In her evening presentation entitled "Across the Northern Region--from cedar groves to tall grass prairies," Janet Johnson provided a look at the beauty and the immense intrinsic values of research natural areas. She also pointed out that it is dedicated people such as you who make research natural areas possible, useful, and even fun.

We found through these many presentations, from some outstanding poster displays, and by numerous person-to-person conversations, that there are many examples of extraordinarily good stewardship on research natural areas and that baseline data are being collected in quite a few locations. Surely, as one participant stated, "We've come a long way," and we are progressing. And most of all, we found such a high degree of dedication and spirit of cooperation among participants, that we're convinced that research natural areas are here to stay. Yes, Jerry Franklin, we met your hopes for a successful symposium. Challenges were presented, needs were stated, and ideas were explored. Implementation of these ideas through diligence and perseverance can lead the way to a fruitful era of baseline monitoring and research in our natural areas.

ROCKY MOUNTAIN FRONT GRIZZLY BEAR MONITORING AND INVESTIGATION

Keith Aune and Tom Stivers

From 1977 to 1983, grizzly bear research was conducted along the east slope of the Rocky Mountains, an area that includes The Nature Conservancy's Pine Butte Preserve. The objectives of the study include (1) to delineate and define essential habitat and important use areas within the study area, (2) to determine impacts associated with gas and oil exploration, and other human activities, and (3) make recommendations to protect and maintain grizzly populations and habitat.

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MONTANA'S RIPARIAN AND WETLAND IMPROVEMENT PROGRAM

Paul Brouha

A slide tape has been prepared with the intent of introducing the concepts of riparian and wetland values to a variety of nontechnical audiences. The potential values lost by improper management of riparian and wetland areas are featured. The concept of a riparian and wetland tax incentive and tax credit program to foster proper management of these is introduced.

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FIFTY YEARS OF SUCCESSION IN YELLOWSTONE NATIONAL PARK MEASURED ON PERMANENT PLOTS

Don G. Despain

As part of a general vegetation survey of the park, four permanent plots were established in 1935 to document plant succession in Yellowstone's forests. Each plot was 1 chain (66 ft) square and all living trees, seedlings, and saplings were located on a plot map. Record was made of species, height, and, for trees over 1.5 dbh, diameter and growth increment during the first 10 years and last 20 years. One of the plots has since been destroyed by construction and one has been lost, but the other two were remeasured in 1957 and again in 1976.

One of the remaining plots is in a Douglas-fir forest (Pseudotsuga menziesii/Symphoricarpos albus HT) in the montane zone at 6,270 ft elevation. The other is in a subalpine, old-growth, lodgepole pine stand (Abies lasiocarpa/Thalictrum occidentale HT) at 8,280 ft elevation.

The most striking result of the remeasurement is the lack of change that has occurred in the intervening years. In the lower stand, only five trees have died, all subordinates. None have become established. Basal area increased from 16 to 20 sq. ft. In the upper stand, four trees and five saplings died. Seedlings and saplings increased by 97 individuals. Basal area increased from 22.5 to 25 sq. ft. These results emphasize that succession is a very slow process in Yellowstone's cool, dry environment.

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METHODS FOR MEASURING SOIL DETERIORATION

William C. Fanning

Soil deterioration data of the Intermountain rangeland ecosystem has historically been difficult for the Bureau of Land Management to acquire due to budget limitations and the ease of using subjective techniques. The BLM's Butte District, Butte, Montana, is attempting to quantify soil deterioration to determine long-range erosion and compaction trends using objective methods. The methods include channel geometry of gullies and erosion point frame for erosion and bulk density (clod method) and the soil penetrometer for compaction.

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RESEARCH NATURAL AREAS IN IDAHO

Douglass M. Henderson and Charles A. Wellner

Thirty-two research natural areas or equivalents have been established in Idaho. These are distributed among agencies as follows: USDA Forest Service - 20 RNA's and 2 botanical areas, USDI Bureau of Land Management - 1 RNA, USDI National Park Service - 1 RNA, Idaho Department of Parks and Recreation - 3 RNA's, Idaho State University - 1 RNA, The Nature Conservancy - 4 Nature Preserves. Thirteen of these established areas were the result of work by the Idaho Natural Areas Coordinating Committee.

The Idaho Natural Areas Coordinating Committee, a volunteer organization of interested citizens, was organized in 1974 to further the selection and designation of research natural areas. The Committee is composed of six technical committees: forests, grasslands and shrublands, alpine, aquatic situations, rare plants, and rare animals. The Committee cataloged and classified natural diversity in Idaho by geomorphic provinces and developed a plan for selection of candidate research natural areas. It cooperated with the Forest Service and the Bureau of Land Management in selection of candidate areas and has recommended candidate areas to all National Forests and Bureau of Land Management Districts in Idaho. Candidate National Forest areas total 100 and Bureau of Land Management areas total 35.

Members of the Idaho Committee have prepared several publications on natural diversity and research natural areas in Idaho.

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PRESCRIBED BURNING AND WOOD HARVESTING IN THE GREAT BASIN: IMPLICATIONS FOR PINYON-JUNIPER RNA's

Susan Koniak and Richard L. Everett

Pinyon-juniper woodlands decrease in understory diversity and cover with increasing tree dominance. To maintain a variety of successional stages within pinyon-juniper research natural areas, prescribed burning and wood harvesting may be used in lieu of natural perturbations. In the Great Basin, chronosequences for species following wildfire and early successional models for prescribed burns and tree harvesting have been developed that can aid in predicting plant response.

Pretreatment vegetation, aspect, elevation, soil, seed reserves, post-treatment precipitation, and slash disposal after harvesting are the primary determinants of post-treatment vegetal response. Understory species generally retain or augment their pretreatment levels of occurrence and cover after burning or harvesting. Shrubs that regenerate by seed are reduced after burning, but return to preburn levels within 5 to 10 years. Few species occur on postburn or harvest stands that are not evident in mature woodlands. If pretreatment vegetation is not known, previously determined species preference for aspect and elevation can help in predicting post-treatment response. Low precipitation following burning tends to increase the annual component of the vegetation. Burning slash following harvesting can reduce plant response. Lop and shatter appears to be the best slash treatment for enhancing postharvest vegetal response.

Post-treatment succession in pinyon-juniper woodlands relies on the sequential dominance of the site by understory species present immediately after disturbance based mainly on their longevity or life cycles. When tree species are eliminated from a site, reentry of the species into the plant community depends upon perennial nurse plants associated with late successional stages. The successional cycle following harvesting is generally shorter that the cycle following fire. The remnant understory plants provide a seed source that can rapidly replenish the understory vegetation. Young trees left on the site quickly dominate the area.

The selection of management alternatives in pinyon-juniper woodlands should be based on expected vegetal response and economic concerns. Prescribed burning has the highest potential for successful ignition, good understory response, and least loss of wood products in the ecotonal areas between pinyon-juniper and sagebrush. Currently, wood harvesting is only economically feasible in accessible, fully stocked stands. Selection of sites with desirable understory species followed by proper slash disposal will facilitate the return of high quality vegetation on the site after harvesting. To prevent waste of wood products, fully stocked stands should only be burned if harvesting is not feasible. High elevation sites and midelevation north and east slopes would produce the most desirable postburning vegetal response.

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MONITORING SOIL CLIMATE

Al Martinson, Bill Basko, Lou Kuennen, and Marci Gerhardt

Soil moisture and temperature have been monitored on the Flathead National Forest since November 1979. These data are used to classify soils, to aid in making silvicultural decisions and to determine when soils are least susceptible to compaction. Soil moisture trends appear to be related to precipitation patterns. In winter when snow covers the ground, and in spring during snow-melt and spring rains, soils are approaching field moisture capacity. In late June or July soils begin to dry out. Soils reach their driest moisture level between August and October. Fall rains, which come between October and December, bring soil moisture up to field capacity. Soil temperatures in winter are seldom below freezing. It appears that snowpacks insulate the soil enough to prevent freezing.

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WATER QUALITY MONITORING ON THE LOLO NATIONAL FOREST

Arne E. Rosquist

National Forests are required to protect and maintain water quality for fish habitat, domestic consumption, recreation, and other downstream uses. Instream monitoring of water quality is one way of assessing how well this objective is met. Project monitoring on the Lolo National Forest is conducted primarily to assess the effects of road construction and timber harvest on the total sediment load of Forest streams. Other activities on National Forest lands also have the potential to alter water quality. Water monitoring techniques employed and factors measured are determined by both type of activity and water use.

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STATE OF WASHINGTON NATURAL AREA PRESERVE SYSTEM: MANAGEMENT AND MONITORING

Mark V. Sheehan and S. Reid Schuller

Over 30 state and private natural area preserves (NAP) comprise the Natural Area Preserve System in Washington. They are set aside to serve as gene pool reservoirs for native plant and animal species, especially rare, threatened or endangered organisms; to provide outdoor laboratories for scientific research and education; and to serve as baselines to be compared with similar managed ecosystems.

NAP's are managed by the Department of Natural Resources, Washington State University, University of Washington, and the Nature Conservancy. The management of NAP's is guided by a general policy that states: (1) natural ecological processes should be allowed to operate unimpeded by human encroachment or intervention; (2) each area will be managed to maintain the feature(s) and governing natural processes for which it was designated; and (3) NAP's are to be used primarily for scientific and educational purposes.

The acceptable uses of an NAP are guided by a management plan. This plan lists the significant features within an NAP, management needed to maintain or restore each feature, and management issues that may require future attention, such as the control of exotic species.

A monitoring program has been established for the NAP system. Its purposes include the identification of factors affecting preserve integrity, the tracking of community structure and composition, and the tracking of shifts in selected species populations. Baseline data such as provided by floral and faunal surveys, permanent vegetation plots, permanent photopoints, mapping of significant features and censusing of selected species are collected. An ongoing inventory is maintained as part of the monitoring effort.

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More than 400 research natural areas have been established in the United States, and a similar number are under consideration as additions. To fulfill their research and educational expectations, these areas require both adequate baseline information and good management to perpetuate their naturalness. These proceedings include papers by prominent scientists of the Northwest who address many aspects of the planning, design, sampling, analysis, and archiving of data needed for effective monitoring for a wide range of biological systems. Also included are case examples and papers dealing with the special considerations necessary for grazing and fire management in research natural areas.

KEYWORDS: research natural areas, natural areas, baseline monitoring, monitoring, fire management, grazing.

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)